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NASA Geodynamics Program: Annual Report for 1980

Geodynamics Program Office

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Table of Contents

I. INTRODUCTION

This document is the second annual report of the NASA Geodynamics Program. Its purpose is to inform interested agencies and individuals of the status, progress, and future plans of the program. The intention of the Geodynamics Program Office is to issue similar reports each year.

The first annual report (NASA, 1980c) contained a section of background and historical information, to bring the reader up to 1979 since the beginning of the program as the National Geodetic Satellite Program. The historical section is omitted here. For the first time we include a list of publications of research results supported by the Program (Appendix 3).

HIGHLIGHTS AND ACHIEVEMENTS OF 1980

In 1980 the detailed planning and organization begun in 1978-1979 was continued. Comments were received from recipients of the Geodynamics Program Plan (NASA, 1979a) and, informally, from several advisory committees: the National Academy of Sciences' Panel on Crustal Movements Measurements, Committees on Geodesy and on Seismology, Committee on Earth Sciences of the Space Science Board; and from NASA's Advisory Subcommittee on Geology and Geodynamics.

Among the highlights of 1980 were the following:

1. The Crustal Dynamics Project Plan was approved, and the Crustal Dynamics Project initiated (NASA, 1979c).

2. An agreement was signed between NASA, USGS, NSF, the Defense Mapping Agency, and the National Geodetic Survey (a NOAA agency), establishing a coordinated Federal program for the application of space technology to geodynamics. The agreement provides for a Program Review Board at management level, and an Interagency Coordinating Committee at program office level. The ICC is a continuation of an informal coordinating committee which had been meeting since early 1979.

3. The International Association of Geodesy, one of the constituent associations of the International Union of Geodesy and Geophysics, established a Commission on International Coordination of Space Techniques for Geodesy and Geodynamics. The Commission President is Prof. I. I. Mueller, a long-time participant in NASA's Geodynamics Program. Secretaries of CSTG are Prof. J. Kovalevsky (France), Prof. A. Massevitch (USSR), and Dr. E. A. Flinn, Chief Scientist of the NASA Geodynamics Program.

4. The Transportable Laser Ranging Station (TLRS), designed and built by the University of Texas at Austin, was completed, checked out, and deployed to the Jet Propulsion Laboratory for TLRS/ARIES intercomparison (Laser/VLBI Intercomparison Session IV) before being put into service in the Crustal Dynamics Project in early 1981.

5. Comparison of VLBI and laser ranging baseline length determinations at observatory sites in New England, Texas, and California showed agreement between the two methods to better than approximately five centimeters.

6. An Announcement of Opportunity for Crustal Dynamics Data Use was issued in October 1980. Approximately 90 proposals were received in response to this AO, including approximately sixteen foreign investigations. Investigations will be selected in mid-1981, and will begin in late 1981.

7. Analysis of the laser ranging observations at Quincy and Otay Mountain (California), a continuation of the previous San Andreas Fault Experiment measurements which have been acquired since 1972, showed good agreement with past measurements, and strengthen the conclusion that the baseline length between these two sites is decreasing at a rate of approximately 8 cm/year - a result consistent in direction but different in magnitude from that predicted by plate tectonics theory.

8. The Magsat satellite re-entered the earth's atmosphere. The mission objectives were successfully accomplished. Magnetic field models were provided to USGS for use in preparation of magnetic charts and maps.

9. The International Council of Scientific Unions (ICSU) approved a request from the International Union of Geodesy and Geophysics and the International Union of Geological Sciences to establish a successor project to the highly successful International Geodynamics Project, which had been approved for the period 1971-1980. The new project, called the International Lithosphere Program (ILP), will be conducted through 1989 by the Inter-Union Commission on the Lithosphere. The scientific importance of space geodynamics is indicated by the fact that two of the five scientific objectives of ILP cannot be accomplished without a global program of space measurements of plate movement and deformation. Dr. R. A. Price of the Canadian Geological Survey is President of the Commission, and Dr. E. A. Flinn is Secretary-General.

10. The Second Annual NASA Geodynamics Program Review was held in early 1980, and attended by most of the program participants. The five-day meeting consisted of presentations and discussion of scientific results.

11. A Gravsat User Working Group was formed by NASA, and met to continue the studies of a gravity field mission begun by the National Academy of Sciences in 1978. A Federal Gravsat panel, established under the auspices of the Satellite Geodesy Applications Board, developed a plan for joint agency participation in the Gravsat mission.

12. A brassboard model of the Gravsat satellite-to-satellite tracking system and simulation of the drag-free system were initiated. (Recent results have confirmed that the required tracking accuracies are entirely feasible.) Computer simulations show that the Gravsat mission as presently configured can improve the accuracy of gravity field models by two to three orders of magnitude.

13. NASA supported the 1980 Project MERIT observing campaign in August-October 1980 by concentrating VLBI and laser ranging observations in this period to the maximum extent possible.

14. Fifty-nine independent baselines were measured in 1980 using both laser ranging and VLBI; this number does not include baselines measured using European stations. For comparison, 55 independent baselines were measured in 1979, and the Crustal Dynamics Project plans to measure 124 in 1981.

15. An interagency plan for geodetic use of the DOD's Global Positioning System satellites was prepared (NASA et al., 1980a).

16. A plan for laser development was published (NASA, 1980a).

II. GEODYNAMICS PROGRAM STRUCTURE AND STATUS

A. PROGRAM SCOPE AND OBJECTIVES

We summarize here the scope of the NASA Geodynamics Program and its objectives. For its historical development, see the Geodynamics Program Annual Report for 1979 (NASA, 1980c).

The objectives of the NASA Geodynamics Program are: (1) to contribute to understanding of the solid earth, in particular the long-term crustal processes associated with natural hazards and resources, and the structure and internal composition of the earth; (2) to facilitate the establishment of new geodynamics measurement services requiring precise position determination.

Achievement of these objectives depends on the development, demonstration, and use of techniques for measuring crustal motion and deformation and on improved measurement of the earth's gravity and magnetic fields. The program includes research in modeling of crustal processes, earth rotational dynamics, and the geopotential field; this research is a necessary part of the program. Studies of new instrumentation and space mission concepts are also supported.

The principal space techniques currently available for precise measurements of crustal motion and deformation, polar motion, and earth rotation are very long baseline interferometry (VLBI) using signals from extragalactic radio sources or from satellites, and laser ranging to the Moon and to man-made satellites such as Lageos. The VLBI and satellite laser ranging methods employ both fixed and mobile stations.

The status of elements of the Geodynamics Program are described in the following sections. Further description of the research program results is given in Section III.

B. CRUSTAL DYNAMICS PROJECT

Beginning in FY 1980, several smaller projects (SAFE, PPME, ARIES) were combined to form the Crustal Dynamics Project. This Project is managed by the Goddard Space Flight Center (GSFC) with the support of the Jet Propulsion Laboratory (JPL). Other participants include the Smithsonian Astrophysical Observatory (SAO), the University of Texas at Austin, the University of Hawaii, the Massachusetts Institute of Technology, and the Northeastern Radio Observatory Corporation (NEROC).

The objectives of the Crustal Dynamics Project are to measure and model:

1. Regional deformation and strain changes related to earthquakes at the plate boundary in the western U.S. and Alaska;

2. The present relative velocity of major plates, with emphasis on the North American and Pacific Plates and those plates interacting with the Pacific Plate;

3. Internal deformation of the North American and Pacific Plates;

4. Regional deformation in regions whose tectonic setting is similar to that of the Western U.S. and Alaska.

The Crustal Dynamics Project is making use of existing systems (developed to support SAFE, PPME and ARIES), upgrading the performance of those systems, and developing new systems in order to conduct a systematic program of crustal movement and deformation measurements through 1986. This NASA Project is an integral part of the multi-agency Federal program for the application of space technology to crustal dynamics and earthquake research. Cooperative arrangements with other countries either having or planning similar capabilities has resulted in extension of project activities to a broad-based global research program in geodynamics. Investigators selected under the October 1980 Announcement of Opportunity for Crustal Dynamics will form an Investigator's Working Group and will become part of the Project beginning in 1982.

The location and dates of operation of funded laser and VLBI systems and cooperating stations in other countries is given in Table II-1.

TABLE II-1

STATIONS AND LOCATIONS FROM WHICH LASER AND/OR VLBI DATA ARE AVAILABLE *

Year 74	75	76	77	78	79	80	Station	Geodetic Latitude	East Longitude
							Goddard Laser Data		
x	x	x	x	x	x	x	Greenbelt (GSFC) Md.	39°01'	- 76°50'
x		x			x		Quincy, California	39 58	-120 56
x		x	x	x	x		Otay Mt., Cal.	32 36	-116 50
	x	x		x			Bermuda	32 21	- 64 39
	x	x		x			Grand Turk	21 28	- 71 08
	x	x	x	x	x	x	Patrick AFB, Fla.	28 14	- 80 36
		x			x		Bear Lake, Utah	41 56	-111 25
			x	x	x	x	Westford, Mass (Haystack Obs.)	42 37	- 71 29
			x	x	x	x	Big Pine, Calif. (Owens Valley RO)	37 14	-118 18
				x	x		Goldstone (DSS-14), Ca.	35 25	-116 53
					x	x	Goldstone (DSS-13), Ca.	35 15	-116 48
					x	x	American Samoa	-14 20	-170 44
					x	x	Yaragadee, Western Australia	-29 03	115 21
					x	x	Kwajalein	9 24	167 29
					x	x	Ft. Davis, Texas (McDonald Obs.)	30 41	-104 01
						x	Haleakala, Maui, Hawaii (LURE Obs.)	20 42	-156 15
							SAO Laser Data		
	x	x	x	x	x	x	Mt. Hopkins, Arizona	31 41	-110 53
	x	x	x	x	x	x	Arequipa, Peru	-16 28	- 71 30
	x	x	x	x	x	x	Natal, Brazil	- 5 56	- 35 10
		x	x	x	x	x	Orroral Valley, Australia	-35 38	148 57
							European Laser Data		
			x	x	x	x	Kootwijk, Netherlands	52 11	5 49
			x	x	x	x	Wettzell, W. Germany	49 09	12 53
			x	x	x		San Fernando, Spain	36 28	- 6 12
							Lunar Laser Data		
x	x	x	x	x	x	x	Ft. Davis, Texas (McDonald Obs.)	30 41	-104 01
		x					Haleakala, Maui, Hawaii (LURE Obs.)	20 42	-156 15
					x	x	Orroral Valley, Australia	-35 38	148 57

TABLE II-1 (continued)

		Year						Geodetic	East
74	75	76	77	78	79	80	Station	Latitude	Longitude
							Observatory VLBI Data		
x	x	x	x	x	x	x	Westford, Mass. (Haystack Obs.)	42 37	- 71 29
x	x	x					Goldstone (DSS-14), Ca.	35 26	-116 53
x	x	x	x	x	x	x	Greenbank, W. Va. (NRAO)	38 26	- 79 50
x			x	x	x	x	Onsala Space Obs., Onsala, Sweden	57 24	11 56
		x	x	x	x	x	Big Pine, Calif. (Owens Valley RO)	37 14	-118 17
					x	x	Efflesberg, W. Germany	50 31	6 53
						x	Ft. Davis, Texas (Harvard RAS)	30 38	-103 57
							Mobile Station VLBI Data		
x	x	x	x		x		Goldstone (DSS-14), Ca.	35 26	-116 53
			x		x	x	Goldstone (DSS-13), Ca.	35 15	-116 48
x	x	x	x	x	x	x	Pasadena, California (Jet Prop. Lab.)	34 12	-118 10
	x	x	x	x	x	x	Big Pine, California (Owens Valley RO)	37 14	-118 17
	x		x				Malibu, California	34 04	-118 39
		x	x			x	Palos Verdes, Calif.	33 45	-118 24
		x	x				Pearblossom, Calif.	34 31	-117 55
			x			x	La Jolla, California	32 52	-117 15
			x				San Francisco, Calif.	37 48	-122 27
					x		Quincy, California	39 58	-120 56
					x		Otay Mt., Calif.	32 36	-116 50

* Some data taken earlier than 1974 is also available.

In 1980 an engineering version of a 4m mobile VLBI was refurbished for field use and procurement was initiated (for delivery in early 1983) of the first mobile VLBI unit specifically designed for field operations (Figure 1). Procurement was also initiated for a transportable VLBI data system which can be used to directly convert radio astronomy antennas to geodetic VLBI facilities. Also in 1980, the first of an improved version of mobile lasers (Transportable Laser Ranging Station - TLRS-1; see Figure 2) was completed and tested and integration of a modularized laser ranging system (TLRS-2; see Figure 3) was initiated.

The ranging precision of the NASA lasers at present is typically better than 10 cm: the NASA Stalas system has a precision of 1-2 cm, three of the Moblas have precisions of 3-5 cm, five of the Moblas systems have precisions of 6-9 cm, and the TLRS have precisions of 1-2 cm. In 1980 an interim modification of five of the eight Moblas was initiated to improve ranging precision to the 2-5 cm level. This modification will be completed in 1981.

Discussions were also initiated with the Australian Division of National Mapping (Natmap) for modification of the Natmap Lunar Laser Ranging Facility at Orroral for satellite ranging.

The development of laser ranging systems for crustal dynamics applications is described in a plan issued in December 1980 (NASA, 1980b).

The current precision of VLBI systems for position determination is 3 to 6 cm. Upgrading of the VLBI technique is planned to achieve precisions of 1 to 3 cm. A key factor in achieving this performance is accurate correction for path length changes caused by water vapor in the atmosphere. Water vapor radiometers capable of reducing this error source to about 2 cm have been developed. Studies of improvements in instrument calibration and atmospheric modeling designed to reduce the error to the 1 cm level were initiated in 1980.

NASA plans for development of the VLBI method for geodetic applications and interplanetary spacecraft tracking are outlined in a document issued in December 1979 (NASA, 1979b).

In mid-1980, a five-station experiment (Figure 4) was conducted with Moblas systems at Haystack, Massachusetts; Ft. Davis, Texas; Goldstone, California; Owens Valley, California; Stalas at GSFC; and VLBI facilities at Haystack, NRAO, West Virginia; Ft. Davis, Goldstone, and Owens Valley. Doppler data were acquired by NOAA at each of these sites and at five other locations in the U.S. The goal was to achieve agreement between the VLBI and laser systems at the 5 cm level or better.

In October 1980 the OVRO-Goldstone-JPL baselines in California were measured using TLRS-1, the 4 meter mobile VLBI at JPL, and Moblas stations at the OVRO and Goldstone VLBI sites. The objective is to verify the accuracy of the mobile VLBI system.

In 1979 and for part of 1980, laser ranging provided initial baselines, with which later measurements will be used to determine the relative motion of the North American and Pacific plates. The sites were located in Hawaii, American Samoa, and Kwajalein in the Pacific; and Ft. Davis, Texas, Goddard Space Flight Center, Maryland, and Owens Valley, California, in North America.

Measurements of the relative plate motion across the North Atlantic using VLBI techniques also began in 1979. Four sites in North America (Westford, Massachusetts; Greenbank, West Virginia; Owens Valley, California; and Ft. Davis, Texas) have been tied to European stations (Onsala, Sweden and Bonn, West Germany). Currently, measurement of intersite distances are being obtained at about one-month intervals between the Ft. Davis and Haystack stations on the North American Plate and the Onsala station on the Eurasian Plate, as part of the NOAA Polaris tests. VLBI measurements have already been carried out between Haystack, Greenbank, Owens Valley, and Goldstone, and these place constraints of less than one cm/year on the internal deformation of this part of the North American Plate (Figure 12).

For regional deformation and North American Plate deformation studies, about 80 sites throughout the continental United States have been recommended by representatives of USGS, NGS, NASA and interested university and government groups. More than 59 of these locations are in the western United States (Figure 5) and 35 of these in California, as shown in Figure 6. These recommendations have been reviewed in terms of scientific value, priorities, implementation feasibility, availability of measurement systems, and measurement strategy, in order to establish the specific sites to be used. Not all the sites will be occupied with the same frequency, since the tectonic problems themselves are varied and the expected rates of motion differ from one region to another.

Both laser ranging and VLBI measurements have been made over the past nine years at several locations in California. These sites have been incorporated into the regional deformation measurement network, in order to make use of the past measurements. Included are eight mobile VLBI sites, five mobile laser sites, and two VLBI base stations. In addition to these locations, other sites in or near California will be visited on a regular basis by mobile systems. These sites were selected partially to link together existing geodetic networks operated by NGS and USGS.

The U.S. regional deformation measurements, which will begin in 1981, will involve about 25 site visits per year. The U.S. sites will evolve into a National Crustal Motion Network which will be monitored by NOAA, beginning in FY 1984.

C. LASER NETWORK OPERATIONS

The NASA satellite laser network, which supports the Crustal Dynamics Project, consists of the eight Moblas operated by GSFC and four fixed lasers operated by the SAO. A high accuracy fixed laser (Stalas) is located at GSFC. In 1980, arrangements with the USAF for operation of a laser in Florida (Ramlas) were discontinued. During the year Moblas lasers were located at GSFC, Haystack, Massachusetts; Ft. Davis, Texas; Owens Valley, California; Goldstone, California; Kwajalein Island, American Samoa; and Yarragadee, Australia. A Moblas was also collocated with the fixed laser at the LURE Observatory at Haleakala, Maui, Hawaii, and remained there while the Hawaii laser operations were interrupted for refurbishment and upgrade of the facility.

SAO lasers were operated in Arequipa, Peru; Natal, Brazil; and Canberra, Australia. A fourth SAO laser at Mt. Hopkins, Arizona, was used to test planned improvements to SAO lasers. These improvements which will be incorporated by earlier 1982 are expected to improve ranging performance to Lageos from 10 cm to 3-5 cm.

D. RESEARCH AND TECHNIQUE DEVELOPMENT (RTD)

The RTD portion of the NASA Geodynamics Program for 1980 included five subprogram elements. These are: Global Earth Structure and Dynamics; Lithospheric Structure and Evolution; Regional Crustal Deformation Modeling; Geopotential Field Modeling; and Advance Systems and Mission Studies. Portions of these activities are carried out through internal research at NASA Centers (GSFC, JPL, and MSFC) and through organizations selected on the basis of proposals submitted in response to an Applications Notice for Geodynamics. For FY 1980, 25 of the 78 proposals received in response to AN:OSTA:80-B were selected for funding. Results of research funded under Geodynamics ATD are described in Section III.

The Advanced System and Mission Studies included continuation of development of SERIES, a geodetic receiver concept using telemetry from the Global Positioning Satellite; a cryogenic gravity gradiometer, and a shuttle time and frequency transfer experiment. New activities were initiated for studies of atmospheric effects on laser and microwave systems, and an airborne laser ranging system for geodetic measurements.

E. MAGNETIC FIELD SATELLITE (MAGSAT)

Magsat (Figure 7) was launched on October 30, 1979, and re-entered the atmosphere on June 11, 1980. It carried a three axis vector magnetometer and a scalar magnetometer. The objectives of the mission were:

1. To obtain an accurate description of the earth's time varying main magnetic field for use in updating and refining world and regional magnetic charts and maps.

2. To compile global crustal magnetic anomaly maps and to interpret them in terms of geological/geophysical models of the crust for natural resource assessment purposes.

During its seven and one-half months in orbit, Magsat provided the most accurate measurements of the global field ever obtained and the first measurements of the vector field in low earth orbit. Initial field models were provided in 1980 to Magsat investigators. Final processing of all Magsat data is expected to be completed in 1982.

F. EARTH GRAVITY FIELD SURVEY MISSION (GRAVSAT)

Requirements for a gravity field mission were studied by the Committee on Geodesy of the National Academy of Sciences in 1979 (NAS, 1979). In 1980 a Gravsat User Working Group (GUWG) was formed by NASA to continue the studies conducted by the NAS and to address questions relating to the feasibility of the mission and the recovery of gravity information (NASA, 1980b). In addition, a Federal Gravsat Panel was initiated under the auspices of the Satellite Geodesy Applications Board to develop a plan (NASA et al., 1980b) for joint agency participation in the Gravsat mission.

The Gravsat mission will use satellite-to-satellite tracking between two low-altitude (160 km) drag-free satellites in polar orbit (Figure 8). A two-way coherent microwave Doppler system will be used to achieve tracking accuracies of one micrometer per second. A brassboard of this tracking system and six-degree-of-freedom simulations of the drag-free system were initiated in late 1980. These studies are planned to be completed in mid 1981.

G. INTERAGENCY COORDINATION

The NASA Geodynamics Program activity was designed to fit the interests and objectives of other Federal agencies, and its activities are closely coordinated with those of other agencies. In particular, it is an objective of the NASA program to assist other Federal agencies in the establishment of improved or new geodetic services using space technology.

In September 1980 an interagency agreement was consummated by NASA, NOAA, USGS, DMA, and NSF, providing for development of space technology for crustal dynamics and earthquake research. The agreement establishes a high-level Program Review Board and an Interagency Coordinating Committee, and requires development of a Federal Implementation Plan for the joint development and use of space systems for the acquisition and analysis of data, for the transition of new technologies from R&D to operational status, and for expansion of the national effort to a global program of geodynamics research. Specifically, three new services are planned: (1) a National Crustal Motion Network by NOAA beginning in 1984; (2) an improved Polar Motion and Earth Rotation Service (Polaris) jointly developed by NASA and NOAA and operational in 1983; and (3) a Local Crustal Motion Network, based initially on the use of SERIES, operated by the USGS beginning in 1983.

In view of the potential importance of GPS to civilian satellite geodesy, an interagency group including NOAA, DOD, NASA, and USGS has prepared a plan for the development and testing of GPS receiver concepts (NASA et al., 1979). This plan will coordinate the activities of the several Federal agencies involved in developing GPS applications, and will provide a basis for testing these concepts and eventually selecting the optimum method, based on costs and performance, for general use. As outlined in the plan, NASA, in proceeding with the development of SERIES (which does not require knowledge of the signal code), NOAA, DMA, and USGS are supporting development of a "tri-agency" receiver based on reconstruction of the GPS carrier phase. Engineering prototypes of SERIES have been built and will be tested by mid-1981. Prototypes of the "tri-agency" receiver are expected to be available in late 1983. A decision as to which receiver will be procured by the participating agencies will be made in 1984, and should result in fieldable units in 1985.

H. INTERNATIONAL COORDINATION

1. Space Systems. In 1980, several laser systems operated by other countries were cooperating with the NASA program. These include a high-accuracy lunar/satellite laser in the Federal Republic of Germany and satellite lasers in France, The Netherlands, Spain, Greece, and Egypt. England, Austria, Japan, and Italy are either planning satellite lasers or have them under development. The Lunar Laser Ranging Station at Orroral Valley, Australia, is also a cooperating station.

Cooperating VLBI systems operated by other countries are those in Onsala, Sweden, and Wettzell, Federal Republic of Germany. A VLBI system under development in Japan is expected to be operational in 1983, to participate in joint US-Japan experiments in 1983-84. The Federal Republic of Germany is planning to procure a VLBI facility dedicated to geodetic use, and other countries (e.g. France, Italy, and England) are considering development of observatory VLBI facilities.

2. Project Merit. Commissions 19 and 31 of the International Astronomical Union have developed plans for a special period of international collaboration in the Monitoring of Earth Rotation and Intercomparison of the Techniques of observation and analysis, Project Merit. The objectives of the projects are: (1) to foster the development of new techniques for the measurement of the variations in the rate and axis of rotation of the earth, (2) to obtain precise data on earth rotation in order to increase our understanding of the causes and effects of the variations, and (3) to make recommendations on the observational basis and organizational arrangements for future international services on earth rotation.

An initial period of observations to test techniques and arrangements for international cooperation occurred from September 1 to November 1, 1980. During this period, special efforts were made by NASA and other organizations to acquire laser and VLBI observations of polar motion and earth rotation and to accelerate the processing of data. Data analysis is now under way, and results will be reported in due course.

I. GEODYNAMICS PROGRAM FUNDING

Total NASA funding for support of the Geodynamics Program is \$25.3M in FY 1980 and \$26.9M in FY 1981 (Table II-2). In general, about 40% of this funding is in support of regional crustal deformation studies in the U.S. Studies of plate motion and deformation are approximately equally supported and account for about 50% of the total. The remainder (10%) supports measurement and modeling of the geopotential fields. A significant portion of Program funds (approximately 70%) is devoted to system development and operations, largely through industry groups and NASA Centers. Research supported at universities, NASA Centers, and other organizations represents about 30% of the total.

TABLE II-2

NASA GEODYNAMICS PROGRAM FUNDING SUPPORT

(IN MILLIONS)

	FY 1980	FY 1981
Crustal Dynamics Project	\$9.6M	\$11.6M
Laser Network Operations	10.8	10.9
Research and Technique Development	3.0	3.2
Magsat Mission	1.6	0.5
Gravsat Studies	0.3	0.7
	\$ 25.3M	\$ 26.9M

III. RESEARCH STATUS AND RESULTS

Five main areas of research are conducted under the Geodynamics Research and Technique Development (RTD) Program. Most of the research results described this section were presented at the Third Annual Geodynamics Program Review, held the week of January 26, 1981, at Goddard Space Flight Center.

A. PROGRAM ELEMENTS AND OBJECTIVES

Before discussing the individual research results, we describe the objective of each of the five main elements that make up the Geodynamics RTD Program. The elements of Geodynamics research are:

1. Global Earth Structure and Dynamics. The objective is to improve our understanding of the dynamics of the earth by development of models of polar motion and earth rotation, global plate motion, and the dynamics of the core; and to improve our understanding of the global structure of the earth, including its crustal magnetization, gravity field, and the evolution of the crust and lithosphere. Formulation of a standard dynamic earth model will be attempted under this program element.

2. Regional Crustal Deformation Modeling. The objective of this element is to conduct modeling studies of crustal deformation in various tectonic settings. These studies are needed to assist in determining what measurements are required and to provide a proper perspective for analysis of data acquired by the Crustal Dynamics Project. The main types of models involved are earthquake mechanism, accumulation of stress and strain, and vertical motion.

3. Lithosphere Structure and Evolution. In this element studies are conducted which are related to the processes which have formed the lithosphere, in order to gain a better understanding of the dynamic mechanisms that are active at present. Under this program element models are being developed that relate to the current state, origin, evolution, and dynamics of the lithosphere. The objective is to derive plate-driving mechanisms, including mantle convection, to explain current plate motion measurements. Emphasis is placed on understanding the nature of subduction and collision zones and lithosphere/mantle rheology.

4. Geopotential Field Models. The objectives of this element are to develop gravity and magnetic field models, to investigate data analysis techniques and software systems, and to support the Non-Renewable Resources and Ocean Research Programs as well as other elements of the Geodynamics Program. Emphasis is placed on use of satellite altimetry and determination of the maximum resolution that can be achieved in the gravity field

analysis with existing data. Magnetic field models (including secular variation) are developed in this area of the program. The development of a data base for ancillary information required for geodynamics investigations, such as gravity anomalies, topography, and bathymetry, is maintained under this element.

5. Advanced Geodynamics Instruments. These studies support the development of new methods for making geodynamics measurements using space systems and techniques.

B. RESEARCH RESULTS

Although there is some overlap between these various elements of the Geodynamics RTD Program, they form a logical framework for this research. Appendix 1 gives a listing of the current investigators, their affiliations, and the title of their current investigations.

1. Global Earth Structure and Dynamics.

This topic falls naturally into two categories: polar motion and earth rotation, and internal dynamics of the earth. We describe current results in rotational dynamics first, and then internal earth structure.

a. Polar Motion and Earth Rotation

One of the significant results comes from the analysis of over four years of upper-air zonal wind data to compute the angular momentum of the global atmosphere, and the resulting changes in length of day. In addition to distinct seasonal and interannual differences, higher frequency fluctuations are evident. Independent measurements of length of day determined by BIH, Lageos, and lunar laser ranging appear to correlate well with the atmospheric data (Figure 9). The atmospheric data will be further studied to determine the regions that contribute most to the observed changes in the total angular momentum.

Several groups are studying laser ranging data to determine polar motion and variations in the earth's rotation rate. Both long-arc and short-arc solutions for Lageos have been determined, and the results compared with BIH and Doppler solutions. The satellite laser ranging data compare favorably with the other solutions, particularly during the MERIT short campaign in late 1980: differences of 0.02 arcseconds and 0.3 milliseconds in length of day are typical.

McDonald Observatory is still the only routinely operating lunar laser ranging observatory, so the types of analysis that can be performed with this data are limited. Variation of latitude and UT0 have been determined from the McDonald lunar laser ranging observations for the period October 1970 to October 1979, and these estimates have been compared with those determined from the pole position and UT1 values obtained using other techniques. The McDonald results agree to within 5.2 milli-arcseconds with the Doppler pole positions and to within 1.6 milliseconds with the BIH UT0. The lunar laser ranging UT0 values were used in conjunction with BIH values of polar motion to determine values of length of day and have been compared with changes in length of day inferred from a time series of global atmospheric angular momentum; the approximate 50 day oscillation recently discovered by Feissel and Gambis at the BIH have appear in both data types and agree closely in both amplitude and phase.

Results of analysis of McDonald Observatory lunar laser ranging data include a value of GM of 398600.45 ± 0.02 km^3/sec^2 and a secular acceleration of the lunar orbital mean longitude of $\dot{n}$ = -23.6 ± 1.5"/century^2, which yields a Q of 12.4 at semidiurnal frequencies. Tidally driven terms in UT1 have coefficients k/c of 0.98 ± 0.18 and 0.92 ± 0.12 at fortnightly and monthly periods, respectively, compared with the theoretical value of 0.94 ± 0.04. Also resulting from the solution are geocentric coordinates of McDonald accurate to 30 cm, information on the lunar orbit, lunar rotation, and reflector coordinates.

Earth orientation parameters derived from Lageos observations were investigated in conjunction with data available from the Green Bank connected element interferometer, Doppler satellite tracking, and the classical optical instruments of the U.S. Naval Observatory. The results indicate that data contributed from each of the above techniques may be useful in a routine service for users. All sets of data may be included in the U.S. Naval Observatory algorithm providing earth orientation parameters and their predictions on a weekly basis.

The comparison of determinations of UT1-UTC by independent techniques in 1979 led to the detection of fluctuations in the length of day with a total amplitude of 0.35 milliseconds and a period of 55 days. As a consequence, the estimated uncertainties (about 1 millisecond) of the five-day values of UT1 derived by the BIH from classical astrometry must be considered realistic. The analysis of this series since 1967 shows that transient fluctuations are often present in the earth's rotation; their amplitudes are several milliseconds and periods 50 to 80 days.

Using VLBI data from 1972 through July 1980, UT1 and the x-component of polar motion have been determined with formal (one-sigma) errors since 1976 of typically 0.2 milliseconds for UT1 and 3 milli-arcseconds for the x-component. Preliminary individual one-day solutions from North American data for the MERIT campaign (Figure 10a and 10b) show smooth changes of earth orientation with peak-to-peak variations of 1.3 milliseconds in UT1 and 15 milli-arcseconds in the x-component (Figure 10a) over an interval of one week.

An accurate description of the elastic-gravitational deformation of a rotating, slightly elliptical earth subject to external gravitational forces has been developed. Some immediate consequences are a more precise theoretical nutation series and a uniformly valid description of the spatially varying Love numbers needed to characterize the behavior of an earth which is not spherically symmetric.

Theoretical estimates of the Chandler period, accounting for the earth's slightly non-hydrostatic equilibrium shape, have been refined and have produced the first correct estimate of Chandler damping caused by anelasticity in the mantle and crust. These results served to significantly tighten bounds on the allowable frequency dependence of anelasticity over the period range of one hour to fourteen months.

The complex interaction of pressure, gravity, and the magnetic field in the core may influence the dynamical motion of the earth. Core effects have been taken into account in computing corrections in the amplitude of the 18.6 year nutation obliquity of the earth.

b. Internal Dynamics

Results of numerical investigations of convection in a plane layer with temperature and depth dependent viscosity over a large parameter range show that when both top and bottom boundaries are stress free, the cold high-viscosity top thermal boundary layer has a dramatic effect on the cell aspect ratio and vertical convective flow structure. The precise manner in which the shallow high-viscosity layer is stripped off may critically affect model results, so that viscosity variations across the top thermal boundary layer may result in significant differences between the interior temperature, surface deformation, and gravity anomalies associated with constant and variable viscosity convection.

Several other models being studied include variable rheology with depth. Using these models, it was found that a shallow region of low viscosity beneath a fault can substantially modify the predicted post-seismic vertical displacements and can lead to a large buildup with time in the post-seismic shear stress ahead of the fault tip. The uplift data following the 1964 Alaskan earthquake are consistent with models including both the subducted slab and a wedge of low viscosity material above the slab. Three-dimensional viscoelastic models of deformation following large thrust earthquakes indicate that surface horizontal velocities of 1 cm/yr or greater may be measurable within 1000 km of the plate boundary.

Locations have been determined of all the laser observatories which were operating during the period 1976 through June 1979. The baselines between the Greenbelt, San Diego and Arequipa (Peru) stations show the best repeatability and these stations are believed to have been the most consistent and accurate systems during these periods. Baseline consistencies between these stations are at the 5 cm level. The heights estimated in these solutions show consistencies at the 10 to 15 cm level.

2. Regional Crustal Deformation Modeling

Several themes characterize current work on crustal movements and crustal deformation. One is the growing need for extension and refinement of the body of concepts that comprise the plate tectonics hypothesis. Near active plate margins the complexities of the real earth must be taken into account in constructing models, since regional-scale deformation of the plates is known to be occurring -- for example, in California, where the global model of Minster and Jordan predicts 5-6 cm/year movement between the Pacific and North American plates, in contrast to approximately 3 cm/year of creep in Central California, no observed movement in Southern California, and approximately 8 cm/year observed point-to-point between Quincy in the Northern Sierra and Otay Mountain on the Pacific plate near San Diego (Figure 11).

Another theme is the need for detailed study and modeling of the rheology of the lithosphere and asthenosphere in order to explain regional deformation. Finally, it is clear that in order to make progress in understanding the important geodynamical problems, the multiple disciplines of geodesy, geophysics, and geology will all have to be involved. Theoretical models draw on concepts and data from field investigations, laboratory analysis, and numerical experimentation.

Kinematic models of plate motion continue to be refined; sources of complexity now being considered include possible non-rigid behavior (e.g., the Indian-Australian plate, which is being sheared along the Ninetyeast Ridge), inclusion of small-area oceanic plates, and departures from ideal behavior near active margins (e.g., inclusion of microplates at the north coast of South America and the west coast of North America in order to explain observed data).

Repeated observations of baseline lengths between VLBI observatories in the US and Europe show no changes at the level of 1 cm/year over the 4000 km baseline between Massachusetts and California since 1972 (Figure 12) and no change at the same level between West Virginia and Massachusetts. Predicted movement between North America and Europe is sufficiently slow that observations up to the present are simply initial-epoch measurements.

Vertical tectonic movements in presumably stable areas continue to be the subject of study. Comparisons between geological and geodetic evidence for movement indicate episodic behavior in the long term. Previous tectonic interpretations of releveling differences may be in error, however, since they have not always taken into account non-tectonic effects such as water withdrawal and systematic errors.

Regional geologists continue to demonstrate the fruitfulness of collaboration between their discipline and those of geodesy and geophysics; examples are studies now being undertaken in the Alps, the Caribbean, China, and Asia Minor.

Several studies continue of time-dependent regional surface deformation associated with earthquakes and fault motion. Creep in both the lower lithosphere and asthenosphere is a possible mechanism for significant postseismic surface motion and restressing of the earthquake slip zone. It appears that significant postseismic motion is possible at distances up to several hundred kilometers from a major fault, on time scales up to a few centuries - depending on the viscosity profile within the earth. One of the most important aspects of regional crustal deformation measurements is the light they may shed on the rheological properties of the asthenosphere.

A new model for coseismic strain release includes the existence of a thin viscous decoupling layer at intermediate depths in the crust; preliminary results presented at the program review appear interesting.

Seismological monitoring in the vicinity of McDonald Observatory in southwestern Texas has revealed active tectonic features which are not indicated by topological trends in the area. Studies of tectonics in several areas, using orbital photographs and Landsat images, are being conducted by several groups.

3. Lithospheric Structure and Evolution

Several studies are being conducted of the relationship between regional geoids and earth structure, particularly in subduction zones. In the Aleutian/Alaskan region, models indicate that gravitationally apparent mass excesses do exist in subducting slabs, and are less than those generally predicted by thermal conduction models.

Residual geoid anomaly profiles for island arcs are being used to constrain numerical models of flow and temperature in subduction zones with a view to obtaining a better understanding of the deep structure of these regions and to address the question of the depth to which the return flow extends. Initial results obtained using a simple Newtonian model show a broad zone of downwelling centered on the trench and predict geoid anomalies of an order of magnitude larger than those actually observed.

Residual geoid anomaly maps show a positive anomaly associated with residual depths south of Australia, and a negative anomaly associated with the West Philippine Basin. These residual geoid anomalies are consistent with anomalous surface wave velocities and with a thermal origin, but not with residual depth. If both residual depth anomalies are caused by the same mechanism, then compositional variations in the uppermost mantle, rather than thermal variations, are probably the cause.

Geoid lows and anomalously shallow sea floor occurring behind drifting continents (south of India, southwest of Australia, and east of North and South America) may be continental wake phenomena. Several differences occur between the oceanic and continental upper mantle (viscosity, composition and lithospheric thickness) that may be important for creating continental wakes; continental tilting and shedding of high-density mantle are probably not important. Less dense mantle rising in the wake of the continent would produce geoid and topographic highs if the mantle beneath the oceanic lithosphere behind the continent were of uniform viscosity. However, if a zone of low viscosity beneath the oceanic plate reduces the normal stress on the base of the lithosphere and the resulting uncompensated topography, a geoid low may occur in association with a topographic high, as observed in continental wakes.

The global intraplate stress field predicted by plate-driving force models has been calculated as a means of testing such models against available observations on midplate stress orientations. The typical magnitude of intraplate stresses is several hundred bars, and local sources of stress of larger magnitude can dominate regional stress. The average changes in stress along faults during earthquakes are typically a small fraction of the total stress. For regional-scale problems, a linear viscoelastic but spatially variable rheology for the lithosphere and asthenosphere has been used to explore the effects of lateral variation in viscosity for both strike-slip and dip-slip earthquakes.

Several investigators are combining data types for multi-disciplinary studies of particular regions; for example, seismic, magnetic, and gravity are being combined with geological and geodetic data for studies in North America.

4. Geopotential Field Models.

Significant progress has been made in modification and improvement of the Geodyn Orbit Determination and Parameter Estimation Program System which is used to recover geodetic and geophysical parameters from satellite data in a state-of-the-art manner. For example, time-dependent drag coefficients and altimeter crossovers were introduced. Still to be incorporated are dynamic allocation of gravity anomalies, surface densities,

and the new parameterization geoid heights. In the general area of modeling, the Jacchia 77 model has been implemented as well as a revised, solid-earth tidal model and general relativity model. The program now integrates in coordinate or ephemeris time instead of atomic time so that relativity can be properly modeled. The program has been rewritten for a vector or parallel processor.

A gravity model has recently been developed using existing data to improve Seasat orbits for more accurate reduction of the spacecraft altimetry. Seasat orbits are now accurate to about 80 cm in radial position. Further gravity model development is currently being done to improve Lageos orbits for more accurate baseline estimation.

Long arc orbital solutions of Lageos laser ranging data for the May 1976 to January 1981 (Figure 13) interval revealed effects caused by ocean and solid earth tide model error and particular spherical harmonic coefficients of the gravity field.

The estimation of GM, the product of the gravitational constant and the earth's mass, from monthly orbital arcs of Lageos, has continued through 1979. An error in the application of the 1976 data that was found earlier this year has been corrected and a complete set of 44 GM estimations has been obtained for the period May 1976 through December 1979. These 44 values give GM = 398600.44 $\pm$ .01 $km^3 sec^{-2}$ compared with 39800.461 $\pm$ 0.026 from the most recent lunar laser and Doppler results.

The semimajor axis of Lageos' orbit is decreasing at the rate of 1.1 mm day^{-1}. The cause of this orbital decay appears to be a combination of charged particle and neutral particle drag. Calculations based on the charged and neutral particle density at the Lageos altitude plus laboratory charge drag experiments give the same order of magnitude as the observed orbital decay. Five other mechanisms (resonance, gravitational radiation, the Poynting-Robertson effect, transfer of spin to orbital angular momentum, and drag from near-earth dust) which can decrease the semimajor axis fail by at least an order of magnitude to explain the observed rate. Three other investigated mechanisms (the Yarkovsky effect, the Schact effect and terrestrial radiation pressure) also fail to explain a secular decrease in the semimajor axis.

The passive geodetic satellite Starlette, which is in an orbit with an altitude of about 1000 km and an inclination of 50°, is complementary to Lageos for precision geodynamic studies. Because of the lower orbital altitude, gravity modeling error causes ephemeris error of a few meters. Four years of precision laser tracking data (1975-1978) have been used to adjust the (36,36) GEM-10B model plus additional terms out to degree 48. Tracking station coordinates were also adjusted in this solution.

A global $1^{\circ} \times 1^{\circ}$ mean anomaly data tape used for geophysical studies and geoid computations, has been continuously updated and used in solutions combining satellite and gravimetric data. The latest update was made in October 1979, where 41973 anomalies were given. Of these values, 6912 anomalies were tentatively identified as being geophysically predicted.

During the past year research was conducted to develop more accurate methods for the calculation of geoid undulations from potential coefficients and gravity anomaly data. Tests show that results are improved by a factor of two using a modification of the Molodensky truncation functions.

The gravity field of the central Pacific area has been measured using satellite-to-satellite tracking between Geos-3 at an altitude of about 840 km and ATS-6 at six earth radii in a geosynchronous orbit. The measurements are about 70 km apart along-track. A low degree and order (less than 12) gravity field was assumed as the reference field in computing the orbits. Using about 50 tracks, these point values were contoured to give a gravity map at an altitude of 840 km. This field shows a dominant wavelength of about 2000 km, often with positive anomalies associated with residual depth anomalies. Significant new anomalies appear near the east Pacific rise trending in the ridge direction and continuing through North America. An additional group of about 50 new passes has been similarly reduced to produce a map which correlates closely with the newest GEM model, the Geos geoid, and with the Seasat geoid.

The global sets of Geos-3 and Seasat altimeter data have been used to produce global $1^{\circ} \times 1^{\circ}$ mean sea surface map (Figure 14). Comparisons have been made between these surfaces and geoids computed from GEM gravity models. The rms difference between the Geos-3 and Seasat mean sea surfaces is 1.1 meters, indicating that sub-meter accuracy has been achieved for both surfaces. Adjustments of the origin of the reference ellipsoid for these surfaces indicated differences generally less than 50 cm.

The Magsat spacecraft successfully acquired high-accuracy vector data from November 2, 1979, through June 11, 1980. Data analysis being performed includes modeling of the earth's core field and study of inferred core fluid properties, determination of characteristics of upper mantle conductivity, modeling of crustal features causing magnetic anomalies, and the study of fields from ionospheric and magnetospheric currents.

An initial selection of Magsat data has been used to derive a series of magnetic field models. In addition to representing the core field well at the Magsat epoch, these models have been used to study the spectrum of the field to aid in separating core and crustal fields (Figure 15). To model the field over longer time spans, and to provide a larger temporal data base for predicting the field, Magsat data has combined with pre-Magsat data from

both satellite and surface measurements to derive a time-dependent representation for the period 1960-1980. Surface data used in such models often has a very large contribution from local crustal sources which has not previously been accounted for. Because of the combination of satellites and surface data, the latest models include a solution representing the anomaly fields at observatories. Use of this technique improves not only the field representation but also the prediction ability of the resulting models.

Preliminary examination of Magsat vector data indicates that it has the accuracy necessary to detect crustal magnetic anomaly fields. The vector data will be used to infer the presence or absence of a remanent component in the anomaly field. For example, a preliminary model of the Bangui anomaly indicates a good probability that it is entirely induced with no remanent component.

The spherical harmonic spatial power spectrum for the geomagnetic field has been related to the sum of the squares of the coefficients of a spherical harmonic expansion of the scalar potential of the field, where the summation, for a particular degree, is over all orders m. The function is invariant under a rotation of the coordinate system, and is basic to a statistical description of the geomagnetic field.

A statistical model for the crustal and core geomagnetic fields has been postulated, and equations have been derived giving the shape of the spherical harmonic spatial power spectrum for both the core and crustal geomagnetic fields. By fitting these equations to available data, equations have been obtained for the numerical values of the spatial power spectra for both the core and crustal geomagnetic field. The equations are not strongly model-dependent. The two spectra are approximately equal for $n = 15$.

Equations have been derived relating the spherical harmonic spatial power spectrum to the average great circle Fourier power spectra of the magnetic field components. These equations have been used to estimate the crustal spherical harmonic spatial power structrum from data reported by Aldredge et al. in 1963 for an approximate great circle track flown by aircraft. It should be possible to use Magsat great circle data to improve this estimate without the need of doing a spherical harmonic analysis to high crustal frequencies. The equations can also be used to test for noise in the vector Magsat data.

5. Advanced Geodynamics Instruments and Studies

Gravsat results were simulated (one micron/sec tracking between two drag-free satellites at 200 km altitude, with 3^{o} separation between them) show that harmonic coefficients (36 x 36) can be obtained with an accuracy of 2 to 3 orders of

magnitude improvement over our present knowledge. The Gravsat harmonic solution was truncated at degree and order 36, showing increasing accuracy for the higher degree terms. However, results also show that to achieve this benefit the harmonic model must be carried out to very high degree (180 or higher) which can be accomplished only with the more advanced computers. The main benefit of the high accuracy in the low degree and order terms is that satellite position due to gravity modeling will be known to better than one centimeter. This is specially beneficial for estimating baselines from Lageos orbits and for estimating radial position on spacecraft orbits with altimetry application.

An error analysis computer program was developed to compute the accuracy of mean anomaly and mean geoid undulations that would be expected from various types of Gravsat missions. The program assumes a polar orbit with global data coverage. The theory used is based on errors in the frequency domain and considerations of truncation effects.

The possibility of using laser doppler tracking between the two Gravsat spacecraft has been studied; the approach would be to have a low-power helium-neon laser on each satellite, and to stabilize the lasers against temperature-controlled Fabry-Perot reference cavities. Telescopes 10 cm or less in aperture would be used. Preliminary results indicate that measurement accuracies of the order of 0.01 micron/sec may be obtained for periods up to at least 100 seconds, so that two orders of magnitude improvement could be made at shorter horizontal wavelengths, provided that comparable accuracy improvements could be made for measuring the along-track position of the optical systems with respect to the proof masses.

Design studies have been conducted of modifying the Spaceborne Laser Ranging Concept to place the laser in an airplane rather than in a spacecraft (the passive retroreflectors are arrayed on the ground). A system (Figure 16) is feasible which can range simultaneously to six ground-based retroreflectors in a 100 km by 200 km grid in a matter of hours. With range biases and single-shot rms errors of the order of one centimeter, such a system could determine baseline lengths of the order of 100 km to better than one centimeter.

A second Lageos satellite would offer substantial benefits over the present situation. Studies show that station position errors can be reduced if the second satellite is placed in a posigrade orbit. A second satellite in the same orbit as Lageos (but 180^{o} out of phase) does not offer great improvement in baseline length accuracies or station position, but does increase operational efficiency by reducing the time required to determine these quantities.

Small highly mobile systems based on use of the Global Positioning System satellites are being developed. The SERIES concept is to use standard VLBI techniques (Figure 17), and it is expected that accuracies of the order of 1-2 cm can be achieved over baseline lengths of 2 to 200 km, with a few hours of on-site acquitition time. Quasar-referenced ARIES mobile facilities will be used to establish a sparse fundamental control grid, as a basis for making the GPS measurements traceable to the time-invariant quasar directions. Recent efforts have been directed toward detailed design and fabrication of a pair of proof-of-concept stations. A new ionospheric calibration system has been demonstrated. The SERIES stations contain lightweight 1.5m diameter dish antennas mounted on trailers. It is expected that the two units will be tested in the field on baselines up to 260 km in length, and their results compared with mobile laser ranging and quasar-based mobile VLBI stations.

Geodynamic requirements for global reference frames have been studied, and problems have been identified with establishing services to maintain and publish reference frame information in the future, the reason being crustal movements which affect the station locations at the accuracies now being achieved.

Monument stability is a fundamental limitation for many types of crustal movements measurements. An "optical anchor" has been installed at Pinon Flat Observatory in California; this device measures the movement of a laser strainmeter piers with respect to the material below. Significant noise level is observed with this instrument, which implies that similar equipment may be desirable in other observatories.

A new method of determining polar motion is being studied; this uses a differencing procedure between quasi-simultaneous laser ranges. If successful, the method would reduce biases from systematic unmodeled orbital effects.

Appendix 1

Geodynamics Investigations Funded Under Applications Notice, 1980

Geopotential Fields

Frey, H. V., Goddard Space Flight Center: Satellite Geopotential Anomalies: Global Distribution and Relation to Surface Data.

Frey, H. V., Goddard Space Flight Center: The Age of Satellite-Observed Magnetic and Gravity Anomalies Using Paleo-Reconstructions.

Langel, R. A., Goddard Space Flight Center: Magnetic Field Modeling, Including Secular Variation.

Marsh, B. D., Johns Hopkins University: Interpretation and Delineation of the Earth's Gravity Field.

Rapp, R. H., Ohio State University: Improvement of the Earth's Gravity Field from Terrestrial and Satellite Data.

Global Earth Structure and Dynamics

Daly, S. F., Jet Propulsion Laboratory: Variable Viscosity Convection.

Dickman, S., SUNY Binghampton: Effects of the Ocean on Polar Motion.

Farrell, W. E., Systems, Science & Software: Measurement of Earth Tides at NASA Tracking Stations.

Felsentreger, T. L., Goddard Space Flight Center: Estimation of Solid Earth/Ocean Tidal Parameters from Satellite Tracking Data.

Goodkind, J. M., University of California at San Diego: Measurement of Vertical Crustal Motion with Superconducting Gravimeter.

Haxby, W. F., Lamont-Doherty Geological Observatory: The Effect of Subduction Zones on the Low-Order Harmonics of the Geoid.

Kaula, W. M., UCLA: Earth Dynamics Analyses.

Parmentier, E. M., Brown University: A Study of the Effects of Moving Continents: Continental Wakes.

Schubert, G., UCLA: Thermal Isostasy in the World's Oceans.

Slade, M. A., Jet Propulsion Laboratory: Post-Seismic Polar Motion Excitation - Numerical Studies.

Smith, M. L., University of Colorado: Geophysical Studies of Nutation and Polar Motion.

Williams, J. G., Jet Propulsion Laboratory: Lunar Laser Ranging Modeling and Data Analysis.

Yoder, C. F., Jet Propulsion Laboratory: Study of the Effect of Inner Core, Fluid Core, and Oceans on Earth Rotation, Nutation, and Polar Motion.

Lithospheric Structure and Evolution

Burke, K., SUNY Albany: Neotectonics of the Northern Caribbean Plate boundary Zone - A Study in Hispaniola.

Dewey, J. F., SUNY Albany: Structural and Tectonic Evolution of the North Anatolian Fault: A Pilot Study in Synthetic Integration of Field Investigations and Landsat Interpretation in the Evolution of Intracontinental Plate Boundaries.

Jones, G., Texas A&M: Altimetry Data and the Deep Structure of Subduction Zones.

Lowman, P., Goddard Space Flight Center: Late Cenozoic Tectonics of the Basin and Range Province.

Molnar, P., MIT: Seismic Wave Velocity Structure in the Downgoing Slab & the Olivine-Spinel Phase Change.

Roufosse, M. C., SAO: Global Study of the Time Evolution of the Lithosphere Using GEOS-3 and Seasat Altimeters.

Watts, A. B., Lamont-Doherty Geological Observatory: The Relationship Between Gravity and Bathymetry in the Pacific Ocean.

Regional Crustal Deformation Modeling

Berger, J., University of California at San Diego: Improvements in Benchmark Stability for Precision Tilt Measurements of Crustal Dynamics.

Cohen, S., Goddard Space Flight Center: Models of Coseismic and Post-Seismic Deformation and Studies of Regional Seismicity.

McAdoo, D. C., Goddard Space Flight Center: Dynamic Processes of Convergent Plate Margins.

Melosh, H. J., SUNY Stony Brook: Finite Element Investigation of Lithosphere Tectonics.

Molnar, P., MIT, Seismicity and Active Tectonics of the Andes and the Origin of the Altiplano.

Mueller, I. I., Ohio State University: Advanced Studies for the Geodynamics Program.

Nur, A., Stanford University: Models for Rupture Mechanics of Plate Boundaries and Crustal Deformation.

Solomon, S. C., MIT, Application of Laser Ranging and VLBI Data to a Study of Plate Tectonic Driving Forces.

Toksöz, M. N., MIT: Geophysical Study of the Structure and Processes of the Continental Convergence Zones Alpine - Himalayan Belt.

Turcotte, D. L., Cornell University: Finite Element Studies of the Surface Strain Field Adjacent to the San Andreas Fault.

Whitcomb, J. H., CIRES (University of Colorado): Modeling of Tectonophysical Distortion from Measurements of Long-Baseline Geodetic Data and Other Geophysical Parameters.

Advanced Studies

Bender, P. L., University of Colorado: GPS Satellite Orbit Determination Using the Reconstructed Carrier Phase Method for Tracking.

Counselman, C. C., MIT: Very Long Baseline Interferometric Geodesy with GPS Satellites.

Resch, G. M., Jet Propulsion Laboratory: Inherent Accuracy of the Water Vapor Radiometry Technique.

Appendix 2

Glossary of Acronyms and Abbreviations

AEM-C	Third Applications Explorer Mission (Magsat)
AFGL	Air Force Geophysical Laboratory
ALSEP	Apollo Lunar Surface Experiment Package
AN	Applications Notice
AO	Announcement of Opportunity
ARIES	Astronomical Radio Interferometric Earth Surveying
ASTP	Apollo-Soyuz Test Project
ATS	Applications Technology Satellite
BIH	Bureau International de l'Heure
CDP	Crustal Dynamics Project
CIRES	Cooperative Institute for Research in Environmental Sciences (University of Colorado)
CSTG	Commission for International Coordination of Space Techniques for Geodesy and Geodynamics
DMA	Defense Mapping Agency
DOC	Department of Commerce
DOD	Department of Defense
DSN	Deep Space Network
EDIS	Environmental Data Information Service
ESA	European Space Agency
FY	Fiscal Year
GEOS	Geodynamic Experimental Ocean Satellite
GPS	Global Positioning System
GSFC	Goddard Space Flight Center
GUWG	Gravsat User Working Group
HO	Haystack Observatory
IAG	International Association of Geodesy
IAU	International Astronomical Union
ICSU	International Council of Scientific Unions
ICL	Inter-Union Commission on the Lithospehre
ILP	International Lithosphere Program
IUGG	International Union of Geodesy and Geophysics
IUGS	International Union of Geological Sciences
JPL	Jet Propulsion Laboratory
Lageos	Laser Geodynamics Satellite
LASSO	Laser Synchronization (of atomic clocks) from Synchronous Orbit
LLR	Lunar laser ranging
LURE	Lunar Ranging Experiment
Magsat	Magnetic Field Mapping Satellite
Mark-III	Advanced VLBI data system
MERIT	Monitoring Earth Rotation and Intercomparison of Techniques
MIT	Massachusetts Institute of Technology
MLRS	McDonald Laser Ranging System
Moblas	Mobile Laser System
MSFC	Marshall Space Flight Center

NAS/NRC	National Academy of Sciences - National Research Council
NASA	National Aeronautics and Space Administration
Natmap	Division of National Mapping (Australia)
NBS	National Bureau of Standards
NGS	National Geodetic Survey
NEROC	Northeastern Radio Observatory Corporation
NGSP	National Geodetic Satellite Program
NOAA	National Oceanic and Atmospheric Administration
NRAO	National Radio Astronomy Observatory
NSF	National Science Foundation
NSSDC	National Space Science Data Center
NSWC	Naval Surface Weapons Center
OSTA	Office of Space and Terrestrial Applications
OVRO	Owens Valley Radio Observatory
Polaris	Polar Motion Analysis by Radio Interferometric Systems
PPME	Pacific Plate Motion Experiment
Ramlas	Range Measurement by Laser System
RTD	Research and Technology Development
RTOP	Research and Technology Operating Plan
SAFE	San Andreas Fault Experiment
SAO	Smithsonian Astrophysical Observatory
SERIES	Satellite Emission Radio Interferometric Earth Surveying
Stalas	Stationary Laser System
STDN	Space Tracking and Data Network
TLRS	Transportable Laser Ranging System
TPM	Tectonic Plate Motion
USGS	United States Geological Survey
USNO	United States Naval Observatory
VLBI	Very Long Baseline Interferometry

Appendix 3

Publications of the Geodynamics Program, 1976-1981

Adams, J., Cornell University: Active Tilting of the Midcontinent: Geodetic and Geomorphic Evidence. EOS Trans. Amer. Geophys. Union 60, 310, 1979.

Adams, J., and Reilinger, R.E., Cornell University: Time Behavior of Vertical Crustal Movements Measured by Releveling in North America. Proceedings of the International Symposium on Redefinition of the North American Vertical Geodetic Networks, G. Lachapelle, ed., Ottawa, 327-342, 1980.

Adams, J., and Reilinger, R.E., Cornell University: Active Tilting of the Oregon and Washington Coastal Ranges. EOS Trans. Amer. Geophys. Union 61, 371, 1980.

Afonso, G., Centre d'Etudes et de Recherches, Geodynamiques et Astronomiques: Role majeur de la trainee electrique dans la decroissance seculaire du demi-grand axe du satellite Lageos. These, Univ. Paris, 1980.

Afonso, G., Centre d'Etudes et de Recherches, Geodynamiques et Astronomiques: Effect of Atmospheric and Charged-Particle Drag on the Lageos Satellite. C.R. Acad. Sci. Paris 290, 1980.

Alexander, S.S., Lee, B., and Petrus, C., The Pennsylvania State University: Relation of Earthquake Focal Mechanisms to Tectonic Structure Features Observed on Satellite Imagery. EOS, Trans Amer. Geophys. Union 61, 290, 1980.

Banerjee, B., The Johns Hopkins University: Modeling the Gravity Field of the Earth by Point Masses. EOS Trans. Amer. Geophys. Union 61, 371, 1980.

Biadgelgne, A., The Pennsylvania State University: Third Derivative Analysis of Gravity Anomalies From Prismatic Sources. MS Thesis, The Pennsylvania State University, November 1979.

Bock, Y., Mueller, I.I., and Pavlis, E., Ohio State University: On the VLBI-Satellite Laser Ranging 'Iron Triangle' Intercomparison Experiment. Radio Interferometry Techniques for Geodesy, NASA Conference Publ. 2115, 435-445, 1980.

Bock, Y., Ohio State University: A VLBI Variance-Covariance Analysis Interactive Computer Program. Report 298, Dept. Geodetic Science, Ohio State University, 1980.

Bowin, Carl O., Woods Hole Oceanographic Institution: Mass Anomaly Estimation From Combined Inversion of Gravity and Geoid Data. EOS Trans. Amer. Geophys. Union, 1981.

Bowin, Carl O., Woods Hole Oceanographic Institution: Upper Mantle Heterogeneity: Comparison of Region South of Australia With Philippine Basin. EOS Trans. Amer. Geophys. Union, 1981.

Bowman, P.L., Purdue University: Correlation of Gravity and Magnetic Data Over North America. MS Thesis, Purdue University, 1978.

Bowman, P.L., Braile, L.W., Chandler, V.W., Hinze, W.J., Luca, A.J., and von Frese: Magnetic and Gravity Anomaly Correlation and its Application to Satellite Data. NASA TM-79702, 1979.

Brammer, R.F., Sailor, R.V., and Lazarewicz, A.R., The Analytical Sciences Corporation (TASC): Magsat Investigation of Lithospheric Magnetic Anomalies in the Eastern Indian Ocean. EOS Trans. Amer. Geophys. Union, May 1981.

Brown, L.D., Miesen, D.L., Reilinger, R.E., and Jurkowski, G.A., Cornell University: Geodetic Leveling and Crustal Movement in the U.S., Part I, Topography and Vertical Motion. EOS Trans. Amer. Geophys. Union, changes and corrections for Spring Annual Meeting, page 4, 1980.

Carter, W.E., Rogers, A.E., Counselman, C.C., and Shapiro, I.I., National Geodetic Survey, National Ocean Survey, NOAA: Comparison of Geodetic and Radio Interferometric Measurements of the Haystack-Westford Base Line Vector. J. Geophys. Res. 85, 1684-2687, 1980.

Chaffin, David L., The Pennsylvania State University: Implications of Regional Gravity and Magnetic Data for Structures Beneath Western Pennsylvania. MS Thesis, The Pennsylvania State University, June 1981.

Chandler, V.W., Bowman, P.L., Hinze, W.J., and O'Hara, N.W., Purdue University: Long-Wavelength Gravity and Magnetic Anomalies in the Lake Superior Region. Geol. Soc. Amer. Special Paper on Geology and Tectonics of the Lake Superior Basin, in press, 1981.

Chandler, V.W., Hinze, W.J., and Braile, L.W., Purdue University: A Preliminary Study of Combined Gravity and Magnetic Analysis. EOS Trans. Amer. Geophys. Union 56, 597, 1975.

Chandler, V.W., Hinze, W.J., and O'Hara, N.W., Purdue University: Regional Analysis of Magnetic and Gravity Anomaly Data in the Great Lakes Region, North America. EOS Trans. Amer. Geophys. Union 59, 378, 1978.

Chandler, V.W., Hinze, W.J., and Braile, L.W., Purdue University: Correlation of Gravity and Magnetic Data Over the Central United States. EOS Trans. Amer. Geophys. Union 59, 226, 1978.

Chandler, V.W., Koski, J.S., Hinze, W.J., and Braile, L.W., Purdue University: Analysis of Multi-source Gravity and Magnetic Anomaly Data Sets by Moving-Window Applications of Poisson's Theorem. Geophysics 46, 30-39, 1981.

Chandler, V.W., Purdue University: Correlation of Gravity and Magnetic Data Over the Great Lakes Region, North America. Ph.D. Thesis, Purdue University, 1977.

Chen, C.H., Chen, W.P., and Molnar, P., Massachusetts Institute of Technology: The Uppermost Mantle P Wave Velocities Beneath Turkey and Iran. Geophys. Res. Lett 7, 77-80, 1980.

Chen, W.P., and Molnar, P., Massachusetts Institute of Technology: Constraints on the Seismic Wave Velocity Structure Beneath the Tibetan Plateau and Their Tectonic Implications. J. Geophys. Res., in press, 1981.

Chen, W.P., and Molnar, P., Massachusetts Institute of Technology: Constraints on the Seismic Wave Velocity Structure Beneath the Tibetan Plateau. Proceedings of the Symposium on the Tibetan Plateau, Beijing, in press, 1981.

Cheney, R.E., and Marsh, J.G., Goddard Space Flight Center: Seasat Altimetry Observations of Dynamic Ocean Currents in the Gulf Stream Region. J. Geophys. Res., submitted, 1980.

Cheney, R.E., and Marsh, J.G., Goddard Space Flight Center: A Preliminary Look at Seasat Altimetry in the Gulf Stream Region. Gulfstream 5, 1979.

Chi, S.C., Reilinger, R.E., Brown, L.D., and Oliver, J.E., Cornell University: Leveling Circuit Closures and Vertical Crustal Movements. J. Geophys. Res. 85, 1469-1474, 1980.

Chi, S.C., Reilinger, R.E., Brown, L.D., and Jurkowski, G.A., Cornell University: Geodetic Leveling and Crustal Movement in the U.S., Part II, Non-Tectonic Influences. EOS Trans. Amer. Geophys. Union 60, 315, 1980.

Christodoulidis, D.C., and Smith, D.E., Goddard Space Flight Center: Geodetic Precisions Expected From Lageos. EOS Trans. Amer. Geophys. Union 61, 1980.

Cohen, S.C., Goddard Space Flight Center: Relationships Among the Slopes of Lines Derived From Various Data Analysis Techniques and the Associated Correlation Coefficient. Geophysics, in press, 1980.

Cohen, S.C., Goddard Space Flight Center: Postseismic Viscoelastic Surface Deformation and Stress 1, Theoretical Considerations, Displacement and Strain Calculations. J. Geophys. Res. 85, 3131-3150, 1980.

Cohen, S.C., Goddard Space Flight Center: Postseismic Viscoelastic Deformation and Stress 2. Stress Theory and Computation; Dependence of Displacement, Strain and Stress on Fault Parameters. J. Geophys. Res. 85, 3151-3158, 1980.

Cohen, S.C., Goddard Space Flight Center: Regional Analysis of Earthquake Occurrence and Seismic Energy Release. NASA TM-81994, August 1980.

Cohen, S.C., Goddard Space Flight Center: Postseismic Rebound Due to Creep of the Lower Lithosphere and Asthenosphere. Geophys. Res. Lett., in press, 1981.

Counselman, C.C, Gourevitch, S.A., King, R.W., Herring, T.A., Shapiro, I.I., Greenspan, R.L., Rogers, A.E.E., Whitney, A.R., and Cappallo, R.J., Massachusetts Institute of Technology: Accuracies of Baseline Determinations by MITES Assessed by Comparisons With Tape, Theodolite, and Geodimeter Measurements. EOS Trans. Amer. Geophys. Union, 1981.

Dalmayrac, B., and Molnar, P., Massachusetts Institute of Technology: Parallel Thrust and Normal Faulting in Peru and Constraints on the State of Stress. In preparation, 1981.

Daly, S.F., Jet Propulsion Laboratory: A Green's Function Approach to Infinite Prandtl Number Convection With Large Viscosity Variations. Geophys. J. Roy. Astron. Soc., submitted, 1980.

Daly, S.F., Jet Propulsion Laboratory: The Effects of Boundary Conditions and Viscosity Variations on the Thermal Structure of Internally Heated Convection. EOS Trans. Amer. Geophys. Union 61, 1109, 1980.

Daly, S.F., Jet Propulsion Laboratory: The Vagaries of Variable Viscosity Convection. Geophys. Res. Lett. 7, 841, 1980.

Daly, S.F., Jet Propulsion Laboratory: A Green's Function Approach to Infinite Prandtl Number Convection With a Depth Dependent Viscosity. IUGG Conference on Mathematical Problems of the Thermal and Dynamical State of the Earth, August 1980.

Dermanis, A., and Mueller, I.I., Ohio State University: Earth Rotation and Network Optimization for Very Long Baseline Interferometers. Bull. Geod. 52, 131-158, 1978.

Dermanis, A., Ohio State University: Design of Experiment for Earth Rotation and Baseline Parameter Determination From Very Long Baseline Interferometry. Report 245, Dept. Geodetic Science, Ohio State University, 1977.

Dermanis, A., Ohio State University: Probabilistic and Deterministic Aspects of Linear Estimation in Geodesy. Report 244, Dept. Geodetic Science, Ohio State University, 1976.

Dewey, J.F., Hempton, M.R., and Saroglu, F., State University of New York at Albany: The East Anatolian Transform Fault. EOS Trans. Amer. Geophys. Union, in press, 1981.

Dewey, J.F., Hempton, M.R., Sengör, A.M.C., and Saroglu, F., State University of New York at Albany: Convergence Mechanisms and Detachment Zones in Eastern Anatolia. EOS Trans. Amer. Geophys. Union 62, 401, 1981.

Dewey, J.F., Kidd, W.S.F., Sengör, A.M.C., and Saroglu, F., State University of New York at Albany: Neotectonics of Eastern Anatolia. EOS Trans. Amer. Geophys. Union 61, 1107-1108, 1981.

Dewey, J.F., Sengör, A.M.C., and Burke, K., State University of New York at Albany: Tectonics of the North Anatolian Transform Fault. Proc. Symposium on Earthquake Prediction Along the North Anatolian Transform, Istanbul. Ferd. Enke Verlag, Stuttgart, in press, 1981.

Dewey, J.F., Sengör, A.M.C., and Burke, K., State University of New York at Albany: The North Anatolian Transform Fault: Its Evolution and Tectonic Characteristics. Proceedings of the Conference on the North Anatolian Fault, Istanbul, April 1980.

Dickey, J.O., Fliegel, H.F., and Williams, J.G., Jet Propulsion Laboratory: Comparison of Earth Rotation Results Using Lunar Laser Ranging, 1981.

Dickey, J.O., Williams, J.G., and Yoder, C.F., Jet Propulsion Laboratory: Results From Lunar Laser Ranging. Report 298, Dept. Geodetic Science, Ohio State University, 1980.

Douglas, B.C., Goad, C.C., and Morrison, F.F., National Geodetic Survey: Determination of the Geopotential from Satellite-to-Satellite Tracking Data. J. Geophys. Res. 85, 5471-5480, 1980.

Dunn, P.J., Smith, D.E., and Kolenkiewicz, R., Goddard Space Flight Center: Latitude Variations of Laser Stations Tracking GEOS-3. EOS Trans. Amer. Geophys. Union, 1976.

Dunn, P.J., Torrence, M.H., Smith, D.E., and Kolenkiewicz, R., Goddard Space Flight Center: Baseline Estimation Using Single Passes of Laser Data. J. Geophys. Res. 84, 1979.

Elsasser, W.M., Olson, P., and Marsh, B.D., The Johns Hopkins University: The Depth of Mantle Convection. J. Geophys. Res. 84, 147-155, 1979.

Fell, P.J., Ohio State University: Geodetic Positioning Using a Global Positioning System of Satellites. Report 299, Dept. Geodetic Science, Ohio State University, 1980.

Felsentreger, T.L., Marsh, J.G., and Agreen, R.W., Goddard Space Flight Center: Analysis of the Solid Earth and Ocean Tidal Perturbations on the Orbits of the GEOS-1 and GEOS-2 Satellites. J. Geophys. Res. 81, 1976.

Felsentreger, T.L., Marsh, J.G., and Williamson, R.G., Goddard Space Flight Center: M2 Ocean Tidal Parameters From Satellite Orbit Data. NASA TM-79571, June 1978.

Felsentreger, T.L., Marsh, J.G., and Williamson, R.G., Goddard Space Flight Center: M_2 Ocean Tide Parameters and the Deceleration of the Moon's Mean Longitude From Satellite Orbit Data. NASA TM-79571, June 1978.

Felsentreger, T.L., Marsh, J.G., and Williamson, R.G., Goddard Space Flight Center: Tidal Perturbations on the Satellite 1967-92A. J. Geophys. Res. 83, 1978.

Ferrari, A.J., Sinclair, W.S., Sjogren, W.L., Williams, J.G., and Yoder, C.F., Jet Propulsion Laboratory: Geophysical Parameters of the Earth-Moon System. J. Geophys. Res. 85, 3939-3951, 1980.

Fliegel, H.F., Dickey, J.O., and Williams, J.G., Jet Propulsion Laboratory: Earth Rotation Using Lunar Laser Ranging Data. EOS Trans. Amer. Geophys. Union 61, 969, 1980.

Fliegel, H.F., Williams, J.G., and Yoder, C.F., Jet Propulsion Laboratory: Evaluation of Polar Motion Data by Lunar Laser Ranging. EOS Trans. Amer. Geophys. Union 61, 212, 1980.

Fliegel, H.F., Jet Propulsion Laboratory: VLBI/Laser Intercomparison Project: Report of Session 2, NASA, 1978.

Fliegel, H.F., Williams, J.G., and Yoder, C.F., Jet Propulsion Laboratory: Evaluation of Polar Motion Data by Lunar Laser Ranging. Deep Space Network Progress Report 42-45, pp. 186ff, June 1980.

Flinn, E.A., NASA Headquarters: Application of Space Technology to Geodynamics: Science 213, 89-96, 1981.

Gaposchkin, E.M., and Wunsch, C., Smithsonian Astrophysical Observatory: On Using Satellite Altimetry to Determine the General Circulation of the Oceans With Application to Geoid Improvement. Revs. Geophys. Space Phys. 18, 725-745, 1980.

Gaposchkin, E.M., Smithsonian Astrophysical Observatory: Averaging on the Surface of a Sphere. J. Geophys. Res. 85, 3187-3193, 1980.

Gaposchkin, E.M., Smithsonian Astrophysical Observatory: Comment on "General Relativity and Satellite Orbits: The Motion of a Test Particle in the Schwarzschild Metric", by D. P. Rubincam. Celestial Mechanics, in press, 1980.

Gaposchkin, E.M., and S. Zerbini, Smithsonian Astrophysical Observatory: Determination of Interstation Baselines by Scalar Translocation. Bull. Geod., submitted, 1980.

Gaposchkin, E.M., Smithsonian Astrophysical Observatory: Kinematic and Dynamic Reference Frames. IAU Colloq. 56, Reference Coordinate Systems for Earth Dynamics, ed. E. M. Gaposchkin and B. Kolaczek, Reidel, 1981.

Gaposchkin, E.M., Smithsonian Astrophysical Observatory: Earth and Ocean Tides From Long-Term Analysis of Satellite Oceans. Space Research 21, 1980.

Gaposchkin, E.M., and B. Kolaczek, eds., Smithsonian Astrophysical Observatory: International Astronomical Union Colloquium No. 56, 1981.

Gaposchkin, E.M., Smithsonian Astrophysical Observatory: Global Gravity Field to Degree and Order 30 From Geos 3 Altimetry and Other Data. J. Geophys. Res. 85, 7221-7234, 1980.

Grafarend, E.W., Mueller, I.I., Papo, H.B., and Richter, B., Ohio State University: Investigations on the Hierarchy of Reference Frames in Geodesy and Geodynamics. Report 289, Dept. Geodetic Science, Ohio State University, 1979.

Grafarend, E.W., Mueller, I.I., Papo, H.B., and Richter, B., Ohio State University: Concept for Reference Frames in Geodesy and Geodynamics. Bull. Geod. 53, 195-213, 1979.

Harris, A.W., and Williams, J.G., Jet Propulsion Laboratory: Earth Rotation Study Using Lunar Laser Ranging. In Scientific Applications of Lunar Laser Ranging, J.D. Mulholland, ed., D. Reidel, 179-190, 1977.

Hawman, Robert B., The Pennsylvania State University: Crustal Models for the Scranton and Kentucky Gravity Highs: Regional Bending of the Crust in Response to Emplacement of Failed Rift Structures. MS Thesis, The Pennsylvania State University, August 1980.

Hayward, K.W., and Kaula, W.M., University of California, Los Angeles: Global Spectral Analyses of Gravity, Topography and Plate Velocity. J. Geophys. Res., in press, 1981.

Hempton, M.R., and Sengör, A.M.C., SUNY Albany: The East Anatolian Transform Fault: Its Age, Offset, and Significance in the Neotectonics of the Eastern Mediterrean. EOS Trans. Amer. Geophys. Union 61, 360, 1980.

Hempton, M.R., Dewey, J.F., and Saroglu, F., SUNY Albany: The East Anatolian Transform Fault: Along-Strike Variations in Geometry and Behavior. EOS Trans. Amer. Geophys. Union 63, 393, 1981.

Hempton, M.R., and Dewey, J.F., SUNY Albany: Structure and Tectonics of the Lake Hazar Pull-Apart Basin, Southeastern Turkey. EOS Trans. Amer. Geophys. Union, 1981.

Herring, T.A. and 16 others, Massachusetts Institute of Technology: Geodesy by Radio Interferometry: Intercontinental Distance Determination With Subdecimeter Precision. J. Geophys. Res. 86, 1647-1651, 1981.

Hinze, W.J., Braile, L.W., Chandler, V.W., and Koski, J.S., Purdue University: North American Transcontinental Magnetic Traverse: Regional Geophysical and Geological Implications. EOS Trans. Amer. Geophys. Union 57, 908, 1976.

Hinze, W.J., Chandler, V.W., and Braile, L.W., Purdue University: Enhanced Interpretation of Magnetic Data by Correlation Techniques. In Workshop on Mathematical Treatment of Anomalies and their Geological Interpretation in Geomagnetic Prospecting, Braunschweigischen Wissenschaftlicher Gesellschaft, vol. 2, p. 23, 1977.

Ho, S., and Smith, A.T., Massachusetts Institute of Technology: A Simple Analytical Solution to Stress Propagation in the Lithosphere. EOS Trans. Amer. Geophys. Union 58, 1234, 1977.

Ho, S., and Smith, A.T., Massachusetts Institute of Technology: Analytical Solution to Stress Propagation in a Two-Dimensional Lithosphere. EOS Trans. Amer. Geophys. Union 60, 953, 1979.

Houseman, G.A., McKenzie, D.P., and Molnar, P., Massachusetts Institute of Technology: Convective Instability of a Thickened Boundary Layer and Its Relevance for the Thermal Evolution of Continental Convergent Belts. J. Geophys. Res., in press, 1981.

Hsui, A.T., and Toksöz, M.N., Massachusetts Institute of Technology: Back Arc Spreading: Trench Migration, Continental Pull or Induced Convection. Tectonophysics 74, 89-98, 1981.

Hsui, A.T., and Toksöz, M.N., Massachusetts Institute of Technology: The Evolution of Thermal Structures Beneath A Subduction Zone. Tectonophysics 60, 43-60, 1979.

Jekeli, C., Ohio State University: Comparison of Undulation Difference Accuracies Using Gravity Anomalies and Gravity Disturbances. Bull. Geodesique 54, 137-147, 1980.

Jekeli, C., Ohio State University: Modifying Stokes' Function to Reduce the Error of Geoid Undulation Computations. J. Geophys. Res., in press, 1981.

Jekeli, C., Ohio State University: Reducing the Error of Geoid Undulation Computations by Modifying Stokes' Function. Report 301, Dep. Geodetic Science, Ohio State University, May 1980.

Jekeli, C., and Rapp, R., Ohio State University: Accuracy of the Determination of Mean Anomalies and Mean Geoid Undulations From a Satellite Gravity Field Mapping Mission. Report 307, Dept. Geodetic Science, Ohio State University, August 1980.

Jones, G.M., Texas A&M University: A One-Dimensional Form of Stokes' Integral for the Computation of Geoid Heights on a Spherical Earth. Geophys. J. Roy. Astron. Soc., submitted, 1981.

Jurkowski, G.A., Brown, L.D., Holdhal, S.R., and Oliver, J.E., Cornell University: Map of Apparent Vertical Crustal Movements for the Eastern United States. EOS Trans. Amer. Geophys. Union 60, 315, 1979.

Kahn, W.A., Goddard Space Flight Center: Ocean Gravity and Geoid Determination. J. Geophys. Res., 1978.

Kahn, W.D., Klosko, S.M., and Wells, W.T., Goddard Space Flight Center: Mean Gravity Anomalies From a Combination Apollo/ATS-6 and GEOS-3/ATS-6 SST Tracking Campaigns. Bull. Geod., in press, 1980.

Kahn, W.D., Klosko, S.M., and Wells, W.T., Goddard Space Flight Center: Mean Gravity Anomalies From a Combination of Apollo/ATS-6 and GEOS-3/ATS-6 SST Tracking Campaigns. EOS Trans. Amer. Geophys. Union, 1980.

Kahn, W.D., Vonbun, F.O., Smith, D.E., Englar, T.S., and Gibbs, B.P., Goddard Space Flight Center: Performance Analysis of the Spaceborne Laser Ranging System. Bull. Geod. 54, 165-180, 1980.

Kamp, A., and van Hulzen, J.J.P., Delft University of Technology: State Transition Matrix Computations for Kalman Filter Orbit Determination From Laser Range Observations. Memorandum M-363, Dept. Aerospace Eng., Delft Univ. Technology, 1980.

Kaula, W.M., University of California, Los Angeles: Problems in Understanding Vertical Movements and Earth Rheology in Earth Rheology. In Isostasy and Eustasy, ed. W. A. Morner, pp. 577-588, John Wiley & Sons, 1980.

Kaula, W.M., University of California, Los Angeles: Material Properties of a Mantle Convection Consistent With Observed Surface Fields. J. Geophys. Res. 85, 7031-7044, 1980.

Kaula, W.M., University of California, Los Angeles: Geodynamic Problems. In Proc. of the 9th GEOP Conference on Applications of Geodesy to Geodynamics, Report 280, Dept. Geodetic Science, Ohio State University, pp. 345-351, 1978.

Kaula, W.M., University of California, Los Angeles: Geophysical Inferences from Statistical Analyses of the Gravity Field. In Proc. of the 9th GEOP Conference on Applications of Geodesy to Geodynamics, Report 280, Dept. Geodetic Science, Ohio State University, pp. 119-141, 1978.

Kaula, W.M., University of California, Los Angeles: Extensions of the Theory of Statistical Analysis on a Sphere. Boll. Geodesia e Scienze 37, 495-505, 1978.

Keller, G.R., Braile, L.W., and Schlue, J.W., Purdue University: Regional Crustal Structure of the Rio Grande Rift From Surface Wave Dispersion Measurements. In Rio Grande Rift - Tectonics and Magmatism. Amer. Geophys. Union Monograph, p. 115-126, 1979.

Keller, G.R., Braile, L.W., and Morgan, P., Purdue University: Crustal Structure, Geophysical Models and Contemporary Tectonism of the Colorado Plateau. Tectonophysics 61, 131-147, 1979.

Klosko, S.M., and Krabill, W., Goddard Space Flight Center: Solid Earth and Ocean Tidal Estimation From Wallops Island C-Band Range Observations of GEOS-3. EOS Trans. Amer. Geophys. Union, 1977.

Kolenkiewicz, R., and Martin, C.F., Goddard Space Flight Center: Seasat Altimeter Height Calibration. J. Geophys. Res., in press, 1981.

Kolenkiewicz, R., Smith, D.E., Dunn, P.J., and Torrence, M.H., Goddard Space Flight Center: Relative Location of Three Mobile Laser Stations. EOS Trans. Amer. Geophys. Union, 1977.

Kolenkiewicz, R., Smith, D.E., and Dunn, P.J., Goddard Space Flight Center: Lageos - Initial Studies. EOS Trans. Amer. Geophys. Union 57, 1976.

Koski, J.S., Chandler, V.W., Braile, L.W., and Hinze, W.J., Purdue University: Enhancement of Gravity and Magnetic Interpretation Through Correlation Analysis. EOS Trans. Amer. Geophys. Union 57, 752, 1976.

Koski, J.S., Purdue University: Internal Correspondence as a Method of Combined Gravity and Magnetic Analysis. MS Thesis, Purdue University, 1977.

Kovalevsky, J., and Mueller, I.I., Ohio State University: Comments on Conventional Terrestrial and Quasi-inertial Reference Systems. IAU Colloq. 56, Reference Coordinate Systems for Earth Dynamics, E. M. Gaposchkin and I. I. Mueller, eds., D. Reidel, 1980.

Krabill, W., Borman, K., and Wells, W.T., Goddard Space Flight Center: GEOS-3 Coherent C-Band Range Rate Data: Precision and Applications. EOS Trans. Amer. Geophys. Union, 1976.

Krabill, W.B., and Borman, K., Goddard Space Flight Center: GEOS-3 Coherent C-Band Tracking Data Reduction and Analysis. NASA TM-73278, September 1978.

Krijnen, H.J., and van Gelder, B.H.W., Delft University of Technology: Testing of Laser Range Measurements to Artificial Satellites and Their Reliability in View of Relative Station Positioning. Dept. Geodesy, Delft Univ. Technology, in press, 1980.

Kumar, M., and Mueller, I.I., Ohio State University: Detection of Crustal Motion Using Spaceborne Laser Ranging Systems. Bull. Geod. 52, 115-130, 1978.

Kumar, M., Ohio State University: Monitoring of Crustal Movements in the San Andreas Fault Zone by a Satellite-Borne Ranging System. Report 243, Dept. Geodetic Science, Ohio State University, 1976.

Langley, R.B., King, R.W., Shapiro, I.I., Rosen, R.D., and Salstein, D.A., Environmental Research & Technology, Inc.: Atmospheric Angular Momentum and the Length of Day: A Common Fluctuation With a Period Near 50 Days. Nature, submitted, 1981.

Langley, R.B., King, R.W., Shapiro, I.I., Rosen, R.D., and Salstein, D.A., Massachusetts Institute of Technology: A Near 50 Day Variation in Earth Rotation and Atmospheric Angular Momentum. EOS Trans. Amer. Geophys. Union, 1981.

Langley, R.B., King, R.W., and Shapiro, I.I., Massachusetts Institute of Technology: Earth Rotation From Lunar Laser Ranging,. J. Geophys. Res., submitted 1981.

Lee, Barbara J., The Pennsylvania State University: Recent Faulting in California Examined From Remotely Sensed Data and Seismicity. MS Thesis, The Pennsylvania State University, August 1980.

Leick, A., and Mueller, I.I., Ohio State University: Defining the Celestial Pole. Manuscripta Geodaetica 4, 149-183, 1979.

Leick, A., Ohio State University: Earth Orientation From Lunar Laser Range-Differencing. Report 263, Dept. Geodetic Science, Ohio State University, 1978.

Leick, A., Ohio State University: The Observability of the Celestial Pole and Its Nutations. Report 262, Dept. Geodetic Science, Ohio State University, 1978.

Lerch, F.J., Goddard Space Flight Center: Determination of the Geocentric Gravitational Constant From Near-Earth Laser Ranging. Geophys. Res. Lett. 5, 1031-1034, 1978.

Lerch, F.J., Klosko, S.M., Wagner, C.A., and Laubscher, R.E., Goddard Space Flight Center: Gravity Model Improvement Using GEOS-3 Altimetry (GEM 10A and 10B). EOS Trans. Amer. Geophys. Union, 1978.

Lerch, F.J., Klosko, S.M., Laubscher, R.E., and Wagner, C.A., Goddard Space Flight Center: Gravity Model Improvement Using GEOS-3 (GEM 9 and 10). J. Geophys. Res. 84, 3897-3916, 1979.

Lerch, F.J., Klosko, S.M., and Wagner, C.A., Goddard Space Flight Center: Goddard Earth Models for Oceanographic Applications (GEM 10B and 10C). Marine Geodesy, in press, 1981.

Lerch, F.J., Marsh, J.G., Klosko, S.M., and Williamson, R.G., Goddard Space Flight Center: Gravity Model Improvement for Seasat. J. Geophys. Res., in press, 1981.

Lerch, F.J., Putney, B.H., Wagner, C.A., and Klosko, S.M., Goddard Space Flight Center: Goddard Earth Models for Oceanographic Applications (GEM 10B and 10C). Marine Geodesy, in press, 1981.

Liu, H.S., Goddard Space Flight Center: Mantle Convection and Subcrustal Stresses Under the United States. Modern Geology 7, 81-93, 1980.

Liu, H.S., Goddard Space Flight Center: Convection-Generated Stress Field and Intra-Plate Volcanism. Tectonophysics 65, 225-244, 1980.

Liu, H.S., Goddard Space Flight Center: Mantle Convection Pattern and Subcrustal Stress Field Under South America. Modern Geology 7, 161-169, 1980.

Longacre, M.B., Hinze, W.J., von Frese, R., Braile, L.W., Lidiak, E.G., and Keller, G.R., Purdue University: Satellite Elevation Magnetic and Gravity Models of Major South American Plate Tectonic Features. IAGA Bull., submitted, 1981.

Luca, A.J., Purdue University: Upward Continuation and Modeling on a Spherical Earth. MS Thesis, Purdue University, 1978.

Mann, P., Hempton, M., Bradley, D., Burke, K., and Dewey, J.F., SUNY Albany: Field Aspects of Pull-Apart Basins. EOS Trans. Amer. Geophys. Union, 1981.

Marsh, B.D., and Marsh, J.G., The Johns Hopkins University: On Global Gravity Anomalies and Two-Scale Mantle Convection. J. Geophys. Res. 81, 5267-5280, 1976.

Marsh, B.D., and Marsh, J.G., The Johns Hopkins University: Reply to Comments by A. Watts. J. Geophys. Res. 83, 3555-3558, 1978.

Marsh, B.D., and Marsh, J.G., The Johns Hopkins University: Short Wavelength Gravity Anomalies in the Pacific. J. Geophys. Res., 1977.

Marsh, J.G., and Chang, E.S., Goddard Space Flight Center: Detailed Gravimetric Geoid Confirmation of Sea Surface Topography Detected by the Skylab S-193 Altimeter in the Atlantic Ocean. Bull. Geod. 50, 291-299, 1976.

Marsh, J.G., and Chang, E.S., Goddard Space Flight Center: Detailed Gravimetric Geoid Computations in Support of the GEOS-III Altimeter Experiment. EOS Trans. Amer. Geophys. Union 57, 901,, 1976.

Marsh, J.G., and Chang, E.S., Goddard Space Flight Center: Global Detailed Gravimetric Geoid. Marine Geodesy, 1977.

Marsh, J.G., and Chang, E.S., Goddard Space Flight Center: Detailed Gravimetric Geoid Computations in North America. Space Research 27, 43-48, 1977.

Marsh, J.G., and Chang, E.S., Goddard Space Flight Center: 5' Detailed Gravimetric Geoid in the Northwestern Atlantic Ocean. J. Marine Geodesy 1, 1977.

Marsh, J.G., and Conrad, T.D., Goddard Space Flight Center: Station Coordinates for the GEOS-3 Altimeter Calibration Area. EOS Trans. Amer. Geophys. Union 58, 371, 1977.

Marsh, J.G., Douglas, B.C., Vincent, S., and Walls, D.M., Goddard Space Flight Center: Tests and Comparisons of Geoids With Skylab Altimeter Data. J. Geophys. Res. 81, 3594-3598, 1976.

Marsh, J.G., Marsh, B.D., Conrad, T.D., Wells, W.T., and Williamson, R.G., Goddard Space Flight Center: Gravity Anomalies Near the East Pacific Rise With Wavelengths Shorter Than 3300 km Recovered From GEOS-3 Satellite-to-Satellite Doppler Tracking Data. NASA TM-79553, December 1977.

Marsh, J.G., Marsh, B.D., Williamson, R.G., and Wells, W.T., Goddard Space Flight Center: The Gravity Field in the Central Pacific From Satellite-to-Satellite Tracking. J. Geophys. Res., in press, 1981.

Marsh, J.G., Martin, T.V., McCarthy, J.J., and Chovitz, B.S., Goddard Space Flight Center: Estimation of Mean Sea Surfaces in the North Atlantic, the Pacific and the Indian Ocean Using GEOS-3 Altimeter Data. Proceedings Second International Symposium on the Uses of Artificial Satellites for Geodesy and Geodynamics, 1978.

Marsh, J.G., Martin, T.V., McCarthy, J.J., and Chovitz, P.S., Goddard Space Flight Center: Mean Sea Surface Computations Using GEOS-3 Altimeter Data. Marine Geodesy 3, 181-200, 1979.

Marsh, J.G., and Martin, T.V., Goddard Space Flight Center: The Seasat Altimeter Mean Sea Surface Model. J. Geophys. Res., submitted, 1981.

Marsh, J.G., Munteanu, M.J., Martin, T.V., McCarthy, J.J., and Chovitz, P.S., Goddard Space Flight Center: Estimation of the Mean Sea Surface in the North Atlantic Using GEOS-3 Altimeter Data. EOS Trans. Amer. Geophys. Union 59, 1978.

Marsh, J.G., and Williamson, R.G., Goddard Space Flight Center: Seasat Altimeter Timing Bias Estimation. J. Geophys. Res., in press, 1981.

Marsh, J.G., and Williamson, R.G., Goddard Space Flight Center: Precision Orbit Analyses in Support of the Seasat Altimeter Experiment. J. Astronaut. Sci. 28, 327-343, 1980.

Marsh, J.G., and Williamson, R., Goddard Space Flight Center: Precision Orbit Computations for Starlette. Bull. Geod. 52, 1978.

Marsh, J.G., Wyatt, G.H., Martin, T.V., McCarthy, J.J., and Chovitz, P.S., Goddard Space Flight Center: Geoid Estimation in the North Atlantic Using GEOS-3 Altimeter Data. EOS Trans. Amer. Geophys. Union 58, 1977.

Martin, C.F., and Kolenkiewicz, R., Goddard Space Flight Center: Calibration Validation for the GEOS-3 Altimeter. NASA TM-80710, June 1980.

Martin, C.F., and Oh, I.H., Goddard Space Flight Center: Utilization of Satellite-to-Satellite Tracking Data for Determination of the Geocentric Gravitational Constant GM. J. Geophys. Res. 84, 1979.

Mather, R.S., Lerch, F.J., Rizos, C., Masters, E.G., and Hirsch, B., Goddard Space Flight Center: Determination of Some Dominant Parameters of the Global Dynamic Sea Surface Topography From GEOS-3 Altimetry. NASA TM-79558, May 1978.

McAdoo, D.C., Goddard Space Flight Center: Geoid Anomalies in the Vicinity of Subduction Zones. J. Geophys. Res., in press, 1980.

McAdoo, D.C., Goddard Space Flight Center: Geoid Anomalies Over the Alaskan/Aleutian Subduction Zone. EOS Trans. Amer. Geophys. Union, 1981.

McAdoo, D.C., Goddard Space Flight Center: Interpretation of Geoid Anomalies in the Vicinity of Subduction Zones. EOS Trans. Amer. Geophys. Union 61, 370, 1980.

McCarthy, D.D., Kaplan, G.H., Klepczynski, W.J., Johnston, K.J., and Spencer, J.H., US Naval Observatory: Comparison of Earth Rotation Parameters Derived by Satellite Laser Ranging and Radio Interferometric Techniques. NASA Geodynamics Program Review, 1981.

McKenzie, D., Watts, A., Parsons, P., and Roufosse, M.C., University of Cambridge: Planform of Mantle Convection Beneath the Pacific Ocean. Nature 288, 1-4, 1980.

Melosh, H.J., and Fleitout, L., State University of New York at Stony Brook: The Earthquake Cycle in Subduction Zones. EOS Trans. Amer. Geophys. Union, in press, 1981.

Melosh, H.J., and Raefsky, A., State University of New York at Stony Brook: The Dynamical Origin of Subduction Zone Topography. Geophys. J. Roy. Astron. Soc. 60, 333-354, 1980.

Melosh, H.J., Raefsky, A., and Slade, M.A., State University of New York at Stony Brook: Surface Deformation Due to Vertical Dip-Slip Faulting in a Non-Newtonian Earth. EOS Trans. Amer. Geophys. Union 60, 316, 1979.

Melosh, H.J., and Raefsky, A., State University of New York at Stony Brook: Anelastic Response of the Earth to a Dip Slip Earthquake. J. Geophys. Res., in press, 1981.

Melosh, H.J., Raefsky, A., and Slade, M.A., State University of New York at at Stony Brook: Geodetic Strategies Following Large Dip-Slip Earthquakes. Radio Interferometry Techniques for Geodesy, NASA Conference Publ. 2115, 1979.

Melosh, H.J., Raefsky, A., and Slade, M., State University of New York at Stony Brook: Postseismic Rebound in a Non-Newtonian Earth. EOS Trans. Amer. Geophys. Union 59, 382, 1978.

Melosh, H.J., and Raefsky, A., State University of New York at Stony Brook: A Simple and Efficient Method for Introducing Faults Into Finite Element Computations. Bull. Seism. Soc. Amer., in press, 1981.

Melosh, H.J., State University of New York at Stony Brook: Post Seismic Motions Following a Strike-Slip Earthquake. Abstract, NASA Geodynamics Program Review, January 25-27, 1981.

Melosh, H.J., State University of New York at Stony Brook: Rheology of the Earth: Theory and Observation. Physics of the Earth's Interior, LXXVII Corso, Enrico Fermi Summer School in Theoretical Physics, Soc. Ital. di Fisica, Bologna, 1980.

Melosh, H.J., State University of New York at Stony Brook: Dynamic Interaction of the Lithosphere and Asthenosphere. Proceedings of Section D, Interunion Commission on Geodynamics, October 2-11, Leningrad, 1978.

Mignard, F., Centre d'Etudes et de Recherches, Geodynamiques et Astronomiques: Effects of the Neutral and Ionized Atmosphere on the Motion of a Satellite. Colloque de Cannes, Space Geodesy and Its Applications, 1981.

Mignard, F., Centre d'Etudes et de Recherches, Effects of the Neutral and Ionized Atmosphere on the Motion of a Satellite: Application to Lageos. Colloque de Cannes, Space Geodesy and Its Applications, 1981.

Molnar, P., and Chen, W.P., Massachusetts Institute of Technology: Constraints on the Amount of North-South Shortening in Tibet During the Cenozoic. Proceedings of the Symposium on the Tibetan Plateau, Beijing, in press, 1981.

Molnar, P., and Gray, D., Massachusetts Institute of Technology: Subduction of Continental Lithosphere. Geology 7, 58-62, 1979.

Molnar, P., and Tapponnier, P., Massachusetts Institute of Technology: A Possible Dependence of Tectonic Strength on the Age of the Crust in Asia. Earth Planet. Sci. Lett. 52, 107-114, 1981.

Mueller, I.I., Ohio State University: Reference Coordinate Systems for Earth Dynamics: A Preview. IAU Colloq. 56, Reference Coördinate Systems for Earth Dynamics, E. M. Gaposchkin and B. Kolaczek, eds., D. Reidel, 1980.

Mueller, I.I., Ohio State University: Positioning by Satellites. Revs. Geophys. Space Phys. 13, 268-270, 1975.

Mueller, I.I., Ohio State University: Error Analysis for the Proposed Close Grid Geodynamic Satellite Measurement System. Report 230, Dept. Geodetic Science, Ohio State University, 1975.

Mueller, I.I., Ohio State University: Three-Dimensional Geodetic Techniques. Proc. Technology Exchange Week, Inter-American Geodetic Survey, Panama City, 463-498, 1979.

Mueller, I.I., and Arur, M.G., Ohio State University: Does Mean Sea Level Slope Up or Down Toward North? Bull. Geod. 117, 289-297, 1975.

Mueller, I.I., Ohio State University: Reference Coordinate Systems for Earth Dynamics. Report 302, Dept. Geodetic Science, Ohio State University, 1980.

Mueller, I.I., van Gelder, B.H.W., and Kumar, M., Ohio State University: Aspects of Positioning Using Satellite-Borne Laser or RF Systems. In New Methods in Space Geodesy, Observations of Artifical Satellites of the Earth, No. 15, USSR Astronomical Council, 150-154, 1975.

Ni, J.F., Reilinger, R.E., and Brown, L.D., Cornell University: Vertical Crustal Movements in the Vicinity of the 1931 Valentine, Texas Earthquake. EOS Trans. Amer. Geophys. Union 61, 289, 1980.

Ong, K.M., MacDoran, P.F., Thomas, J.B., Fliegel, H.F., Skjerve, L.J., Spitzmesser, D.J., Batelaan, P.D., and Paine, S.R., Jet Propulsion Laboratory: A Demonstration of a Transportable Radio Interferometric Surveying System With 3 cm Accuracy on a 307-m Baseline. J. Geophys. Res. 81, 3587, 1976.

Pavlis, E.C., Ohio State University: Error Analysis for a Spaceborne Laser Ranging System. Report 290, Dept. Geodetic Science, Ohio State University, 1979.

Prescott, W., and Nur, A., Stanford University: Accommodation of Relative Motion at Depth on the San Andreas Fault System in California. J. Geophys. Res. 86, 999-1004, 1981.

Raefsky, A., and H.J. Melosh, Jet Propulsion Laboratory: The Dynamical Origin of Subduction Zone Topography: A Numerical Study. EOS Trans. Amer. Geophys. Union 59, 1194, 1978.

Rapp, R.H., Ohio State University: Ellipsoidal Corrections for Detailed Geoid Computations. EOS Trans. Amer. Geophys. Union 61, 938, 1980.

Rapp, R.H., Ohio State University: A Comparison of Altimeter and Gravimetric Geoids in the Tonga Trench and Indian Ocean Areas. Bull. Geodesique 54, 149-165, 1980.

Ravenhurst, C., The Pennsylvania State University: Utility of Digitally Merged Seasat-A, SAR, Landsat MSS, and Magnetic Field Data Sets for Mapping Lithology and Structure. MS Thesis, The Pennsylvania State University, November 1980.

Reilinger, R.E., and Brown, L.D., Cornell University: Neotectonic Deformation, Near Surface Movements and Systematic Errors in the U.S. Releveling Measurements: Implications for Earthquake Prediction. Maurice Ewing Earthquake Prediction Volume, Amer. Geophys. Union, in press, 1981.

Reilinger, R.E., Brown, L.D., and Jurkowski, G.A., Cornell University: Geodetic Leveling and Crustal Movement in the U.S., Part III, Tectonic Deformation. EOS Trans. Amer. Geophys. Union 61, 210, 1980.

Reilinger, R.E., Brown, L.D., and Powers, D., Cornell University: New Evidence for Tectonic Uplift in the Diablo Plateau Region. Geophys. Res. Lett. 7, 181-184, 1980.

Reilinger, R.E., Cornell University: Elevation Changes Near the San Gabriel Fault, Southern California. Geophys. Res. Lett. 7, 1017-1019, 1980.

Reilinger, R.E., Oliver, J.E., Brown, L.D., Sanford, A.R., and Balazs, E.I., Cornell University: New Measurements of Crustal Coming Over the Socorro Magma Body. Geology 8, 291-295, 1980.

Richardson, R.M., and Solomon, S.C., Massachusetts Institute of Technology: Finite Element Modeling of Stress in the Plates Due to Driving Forces. EOS Trans. Amer. Geophys. Union 58, 1234, 1977.

Richardson, R.M., Massachusetts Institute of Technology: Finite Element Modeling of Stress in the Nazca Plate: Driving Forces and Plate Boundary Earthquakes. Tectonophysics 50, 223-238, 1978.

Richardson, R.M., Massachusetts Institute of Technology: Intraplate Stress and the Driving Mechanism for Plate Tectonics. Ph.D. Thesis, Massachusetts Institute of Technology, 1978.

Richardson, R.M., Solomon, S.C., and Sleep, N.H., Massachusetts Institute of Technology: Tectonic Stress in the Plates. Revs. Geophys. Space Phys. 17, 981-1019, 1979.

Richardson, R.M., and Bergman, E.A., Massachusetts Institute of Technology: Finite Element Modeling of Stress along the San Andreas Fault. EOS Trans. Amer. Geophys. Union 60, 952, 1979.

Roufosse, M.C., Smithsonian Astrophysical Observatory Center for Astrophysics: Study of the Walvis Ridge and the Rio Grande Rise Using Geos-3 Radar Altimeter Data. In preparation, 1981.

Roufosse, M.C., Smithsonian Astrophysical Observatory Center for Astrophysics: Study of the Time Evolution of the Lithosphere Using Geos-3 Radar Altimeter Data. In preparation, 1981.

Roufosse, M.C., Smithsonian Astrophysical Observatory Center for Astrophysics: Geoid and Depth Anomalies in the Indian Ocean. EOS Trans. Amer. Geophys. Union, 1981.

Rubincam, D.P., Goddard Space Flight Center: Van der Grintin Formulae. Amer. Cartogr. 7, 176-177, 1980.

Rubincam, D.P., Goddard Space Flight Center: On the Secular Decrease in the Semimajor Axis of Lageos' Orbit. Celestial Mech., submitted, 1980.

Rubincam, D.P., Goddard Space Flight Center: Atmospheric Drag as the Cause of the Secular Decrease in the Semimajor Axis of Lageos Orbit. Geophys. Res. Lett. 7, 468-470, 1980.

Rubincam, D.P., Goddard Space Flight Center: Tidal Parameters Derived From the Perturbations in the Orbital Inclinations. NASA Document X-921-26-72, April 1976.

Rubincam, D.P., Goddard Space Flight Center: The Secular Decrease of the Semimajor Axis. Lageos Tech. Bull. 1, 2-3, 1980.

Sanchez, B.V., Goddard Space Flight Center: The Enhanced Nodal Equilibrium Ocean Tide and Polar Motion. Geofisica Internacional 18, 1979.

Sandwell, D.T., and Poehls, K.A., University of California, Los Angeles: A Compensation Mechanism for the Central Pacific. J. Geophys. Res. 85, 3751-3758, 1979.

Sandwell, D.T., Schubert, G., and Sailor, R.V., University of California, Los Angeles: Geoid Height Across Fracture Zones. EOS Trans. Amer. Geophys. Union 61, 1123, 1980.

Sandwell, D.T., and Schubert, G., University of California, Los Angeles: Geoid Height Versus Age for Symmetric Spreading Ridges. J. Geophys. Res. 85, 7235-7241, 1980.

Sandwell, D.T., University of California, Los Angeles: Green's Functions Relating Heat Flow, Topography, and Gravity to a Point Heat Source. EOS Trans. Amer. Geophys. Union 61, 380, 1980.

Sandwell, D.T., University of California, Los Angeles: The Response of a Moving Lithosphere to a Distributed Heat Source. J. Geophys. Res., submitted, 1981.

Sasao, T., and Wahr, J.M., Cooperative Institute for Research in Environmental Sciences: An Excitation Mechanism for the Free 'Core Nutation.' Geophys. J. Roy. Astron. Soc. 64, 729-746, 1981.

Schilt, F.S., and Reilinger, R.E., Cornell University: Detection of Vertical Fault Displacement by Precise Leveling. Bull. Seism. Soc. Amer., submitted, 1981.

Schutz, B.E., Tapley, B.D., Eanes, R.J., Marsh, J.G., Williamson, R.G., and Martin, T.V., University of Texas at Austin: Precision Orbit Determination Software Validation Experiment. J. Astronaut. Sci. 4, 327-345, 1980.

Schutz, B.E., Tapley, B.D., Eanes, R.J., Marsh, J.G., Williamson, R.G., and Martin, T.V., University of Texas at Austin: Precision Orbit Determination Software Validation Experiment. J. Astronaut. Sci. 28, 327-343, 1980.

Sexton, J.L., and Hinze, W.J., Purdue University: A Magnetic Profile Map of the United States. EOS Trans. Amer. Geophys. Union 61, 1980.

Sexton, J.L., Hinze, W.J., von Frese, R., and Braile, L.W., Purdue University: Long-Wavelength Aeromagnetic Map. EOS Trans. Amer. Geophys. Union 61, 1981.

Slade, M.A., Melosh, H.J., and Raefsky, A., State University of New York at Stony Brook: Non-Newtonian Post-Seismic Motions: A Source of Chandler Wobble? EOS Trans. Amer. Geophys. Union 60, 879-880, 1979.

Smith, A.T., Massachusetts Institute of Technology: Models of Time-Dependent Deformations for Strike-Slip and Thrust Faults. EOS Trans. Amer. Geophys. Union 60, 953, 1979.

Smith, A.T., Yang, M., and Toksöz, M.N., Massachusetts Institute of Technology: Displacement and Stress Propagation in the Lithosphere. EOS Trans. Amer. Geophys. Union 57, 1006, 1976.

Smith, D.E., and Dunn, P.J., Goddard Space Flight Center: Long Term Evolution of the Lageos Orbit. Geophys. Res. Lett. 7, 437-440, 1980.

Smith, D.E., Kolenkiewicz, R., Wyatt, G.H., Dunn, P.J., and Torrence, M.H., Goddard Space Flight Center: Applications of Laser Tracking to the Measurement of Inter-Site Distances. COSPAR Space Research 27, 49-53, Academic Press, 1977.

Smith, D.E., Kolenkiewicz, R., Dunn, P.J., and Torrence, M.H., Goddard Space Flight Center: The Measurement of Fault Motion by Satellite Laser Ranging. Tectonophysics 52, 59-67, 1977.

Smith, D.E., Kolenkiewicz, R., Dunn, P.J., and Torrence, M.H., Goddard Space Flight Center: The San Andreas Fault Experiment, 1972-1974. EOS Trans. Amer. Geophys. Union 57, 233, 1976.

Smith, D.E., Kolenkiewicz, R., and Dunn, P.J., Goddard Space Flight Center: Determination of Polar Motion and Earth Rotation From Laser Tracking of Satellites. IAU Symposium 82, Time and The Earth's Rotation, D. Reidel, 1979.

Smith, D.E., Kolenkiewicz, R., Dunn, P.J., and Torrence, M.H., Goddard Space Flight Center: Determination of Station Coordinates From Lasers. Proc. Second International Symposium on the Use of Artificial Satellites for Geodesy and Geodynamics, 1979.

Smith, D.E., Kolenkiewica, R., Wyatt, G.H., Dunn, P.J., and Torrence, M.H., Goddard Space Flight Center: Geodetic Applications of Laser Ranging. Phil. Trans. Roy. Soc. London A, 529-536, 1977.

Smith, D.E., Lerch, F.J., Marsh, J.G., Kolenkiewicz, R., and Khan, J., Goddard Space Flight Center: Contributions to the National Geodetic Satellite Program by Goddard Space Flight Center. J. Geophys. Res. 81, 1006, 1976.

Smith, M.L., Cooperative Institute for Research in Environmental Sciences: The Theoretical Description of the Nutation of the Earth. Proceedings of IAU Colloq. 56, Reference Coordinate Systems for Earth Dynamics, ed. E.M. Gaposchkin and M.G. Rochester, D. Reidel, 1981.

Smith, M.L., Cooperative Institute for Research in Environmental Sciences: A Normal Mode Study of Wobble and Nutation. Proc. IAU Symposium 78, 1980.

Smith, M.L., and Dahlen, F.A., Cooperative Institute for Research in Environmental Sciences: Period and Q of the Chandler Wobble. Geophys. J. Roy. Astron. Soc., 1981.

Soler, T., Ohio State University: Global Plate Tectonics and the Secular Motion of the Pole. Report 252, Dept. Geodetic Science, Ohio State University, 1978.

Soler, T., and Mueller, I.I., Ohio State University: Global Plate Tectonics and the Secular Motion of the Pole. Bull. Geod. 52, 39-57, 1977.

Solomon, S.C., Richardson, R.M., and Bergman, E.A., Massachusetts Institute of Technology: Tectonic Stress: Models and Magnitudes. J. Geophys. Res. 85, 6086-6092, 1980.

Solomon, S.C., and Sleep, N.H., Massachusetts Institute of Technology: Plate Motions, Intraplate Stress, and the Driving Forces. EOS Trans. Amer. Geophys. Union 58, 367, 1977.

Solomon, S.C., Yang, M., Toksöz, M.N., and Bergman, E.A., Massachusetts Institute of Technology: Tectonic Models of Lithospheric Stress and Strain. NASA Geodynamics Program Review, 1977.

Spence, D.A., and Turcotte, D.L., Cornell University: Viscoelastic Relaxation of Cyclic Displacements on the San Andreas Fault. Proc. Roy. Soc. London A365, 121-144, 1979.

Suarez, G., Massachusetts Institute of Technology: Earthquake Mechanisms and Depth of Faulting in the Central Andes. Abstract, Seism. Soc. Amer. Meeting, 1981.

Tag, P.H., Turcotte, D.L., and Cooper, R.F., Cornell University: The Distribution of Stress and Temperatures During Stable Sliding on the San Andreas Fault. EOS Trans. Amer. Geophys. Union 60, 383, 1979.

Toksöz, M.N., Buck, W.R., and Hsui, A.T., Massachusetts Institute of Technology: Crustal Evolution and Thermal State of Tibet. Proceedings of the Symposium on the Tibetan Plateau, Beijing, in press, 1981.

Torrence, M.H., Dunn, P.J., Smith, D.E., and Kolenkiewicz, R., Goddard Space Flight Center: Polar Motion From Lageos. EOS Trans. Amer. Geophys. Union, 1978.

Torrence, M.H., Kolenkiewicz, R., Smith, D.E., Rubincam, D.P., and Dunn, P.J., Goddard Space Flight Center: Polar Motion and Earth Tides From Laser Tracking. Phil. Trans. Roy. Soc. London A284, 485, 1977.

Turcotte, D.L., Clancy, R.T., Spence, D.A., and Kulhawy, F.H., Cornell University: Mechanisms for the Accumulation and Release of Stress on the San Andreas Fault. J. Geophys. Res. 84, 2273-2282, 1979.

Turcotte, D.L., Cornell University: Stress Accumulation Mechanisms on Strike-Slip Faults. In An Interdisciplinary approach to Earthquake Prediction, A.M. Isika et al., eds., Verlag Vieweg Braunschweig, Wiesbaden, in press, 1981.

Turcotte, D.L., Tag, P.H., and Cooper, R.F., Cornell University: A Steady State Model for the Distribution of Stress and Temperature on the San Andreas Fault. J. Geophys. Res. 85, 6224-6230, 1980.

van Gelder, B.H.W., Ohio State University: Estimability and Simple Dynamical Analyses of Range (Range-Rate and Range-Difference) Observations to Artificial Satellites. Report 284, Dept. Geodetic Science, Ohio State University, 1978.

von Frese, R., Braile, L.W., and Hinze, W.J., Purdue University: Correlation of Long-Wavelength Gravity and Magnetic Anomalies of North America. IAGA Bull 43, 166, 1979.

von Frese, R., Hinze, W.J., and Braile, L.W., Purdue University: Gravity and Magnetic Anomaly Modeling of Mississippi Embayment Crustal Structure at Satellite Elevations. In US Nuc. Reg. Comm., NUREG/CR-1878, 115-131, 1980.

von Frese, R., Hinze, W.J., and Braile, L.W., Purdue University: Long-Wavelength Geophysical Anomalies of North America. EOS Trans. Amer. Geophys. Union 60, 397-398, 1979.

von Frese, R., Hinze, W.J., and Braile, L.W., Purdue University: Mississippi Embayment Crustal Structure From Satellite Elevation Gravity and Magnetic Anomaly Data. EOS Trans. Amer. Geophys. Union 61, 1195, 1980.

von Frese, R., Hinze, W.J., and Braile, L.W., Purdue University: Gravity Anomaly Field of North America at 450 km Elevation. EOS Trans. Amer. Geophys. Union 61, 51, 1980.

von Frese, R., Hinze, W.J., Braile, L.W., and Luca, A.J., Purdue University: Spherical Earth Gravity and Magnetic Anomaly Modeling by Gauss-Legendre Quadrature Integration. J. Geophys. Res., in press, 1981.

von Frese, R., Hinze, W.J., and Braile, L.W., Purdue University: Spherical Earth Gravity and Magnetic Anomaly Analysis by Equivalent Point Source Inversion. Earth Planet. Sci. Lett., in press, 1981.

von Frese, R., Hinze, W.J., and Braile, L.W., Purdue University: Regional Magnetic Model of the Mississippi Embayment. EOS Trans. Amer. Geophys. Union 61, 1981.

von Frese, R., Hinze, W.J., and Braile, L.W., Purdue University: Regional North American Gravity and Magnetic Anomaly Correlations. Geophys. J. Roy. Astron. Soc., submitted, 1981.

von Frese, R., Hinze, W.J., Sexton, J.L., and Braile, L.W., Purdue University: U.S. Aeromagnetic and Satellite Magnetic Anomaly Comparisons. IAGA Bull., submitted, 1981.

von Frese, R., Luca, A.J., Hinze, W.J., and Braile, L.W., Purdue University: Gravity and Magnetic Anomalies at Satellite Elevations Over North America. Amer. Geophys. Union Document E79-002, p. 6, 1978.

von Frese, R., Purdue University: Lithospheric Interpretation and Modeling of Satellite Elevation Gravity and Magnetic Anomaly Data. Ph.D. Thesis, Purdue University, 1980.

Vonbun, F.O., Kahn, W.D., Wells, W.T., and Conrad, T.D., Goddard Space Flight Center: Determination of $5^{\circ} \times 5^{\circ}$ Gravity Anomalies Using Satellite-to-Satellite Tracking Between ATS-6 and Apollo. Geophys. J. Roy. Astron. Soc. 61, 645-658, 1980.

Vonbun, F.O., and Kahn, W.D., Goddard Space Flight Center: Earth's Gravity Field Mapping Requirements and Concept. Bull. Geod., in press, 1981.

Vonbun, F.O., and Kahn, W.D., Goddard Space Flight Center: Strategies for Estimating the Marine Geoid From Altimeter Data. NASA TN D-8285, July 1976.

Vonbun, F.O., and Kahn, W.D., Goddard Space Flight Center: Mean Sea Level Determination From Satellite Altimetry. NASA Document X-921-77-41, March 1977.

Vonbun, F.O., Marsh, J.G., McGoogan, J.T., Leitao, S. Vincent, and Wells, W.T., Goddard Space Flight Center: Skylab Earth Resources Experiment Package (EREP). J. Spacecraft and Rockets 13, 1976.

Vonbun, F.O., Marsh, J.G., and Lerch, F.J., Goddard Space Flight Center: Computed and Observed Ocean Topography: A Comparison. Boundary Layer Meteorology 13, 253-262, 1978.

Wagner, C.A., and Klosko, S.M., Goddard Space Flight Center: Gravitational Harmonics From Shallow Resonant Orbits. Celestial Mechanics 16, 143-163, 1977.

Wagner, C.A., Goddard Space Flight Center: The Geoid Spectrum From Altimetry. NASA TM-79583, July 1978.

Wagner, C.A., Goddard Space Flight Center: The Spectrum of the Geoid From Altimeter Data. EOS Trans. Amer. Geophys. Union, 1977.

Wagner, C.A., Goddard Space Flight Center: The Accuracy of Goddard Earth Models. NASA Document X-921-26-187, 1976.

Wagner, C.A., Goddard Space Flight Center: Geopotential Resonances on Vanguard Orbits. J. Geophys. Res. 82, 915-927, 1977.

Wagner, C.A., Lerch, F.J., Brownd, J.E., and Richardson, J.A., Goddard Space Flight Center: Improvement in the Geopotential Derived From Satellite and Surface Data. J. Geophys. Res. 82, 901, 1977.

Wahr, J.M., Cooperative Institute for Research in Environmental Sciences: Body Tides on an Elliptical, Rotating, Elastic and Oceanless Earth. Geophys. J. Roy. Astron. Soc. 64, 729-746, 1981.

Wahr, J.M., Cooperative Institute for Research in Environmental Sciences: The Forced Nutation of an Elliptical, Rotating, Elastic and Oceanless Earth. Geophys. J. Roy. Astron. Soc. 64, 705-727, 1981.

Wahr, J.M., and Larden, D.R., Cooperative Institute for Research in Environmental Sciences: A Search for the 460 Day Free Nutation Using Lunar Laser Ranging Data, in preparation, 1982.

Wahr, J.M., and Sasao, T., Cooperative Institute for Research in Environmental Sciences: A Diurnal Resonance in the Ocean Tide and in the Earth's Load Response Due to the Resonant Free 'Core Nutation.' Geophys. J. Roy. Astron. Soc. 64, 747-765, 1981.

Wahr, J.M., Sasao, T., and Smith, M.L., Cooperative Institute for Research in Environmental Sciences: Effect of the Fluid Core on Changes in the Length of Day Due to Long Period Tides. Geophys. J. Roy. Astron. Soc., in press, 1980.

Wahr, J.M., and Wyss, M., Cooperative Institute for Research in Environmental Sciences: Interpretation of Postseismic Deformation With a Viscoelastic Relaxation Model. J. Geophys. Res. 85, 6471-6478, 1980.

Wakker, K.F., and Ambrosius, B.A.C., Delft University of Technology: Estimation of the Wettzell Coordinates From Satellite Laser Ranging at Kootwijk. Report LR-296, Dept. Aerospace Eng., Delft Univ. Technology, 1980.

Wakker, K.F., and Ambrosius, B.A.C., Delft University of Technology: A Study on the Determination of the Kootwijk-Wettzell Baseline from Satellite Laser Ranging at These Stations. Report LR-295, Dept. Aerospace Eng., Delft Univ. Technology, 1980.

Wakker, K.F., Ambrosius, B.A.C., and van Hulzen, J.J.P., Delft University of Technology: Kalman Filter Orbit Improvement From Kootwijk Laser Range Observations. Report LR-301, Dept. Aerospace Eng., Delft Univ. Technology, 1980.

Watts, A., and Daly, S.F., Lamont-Doherty Geological Observatory: Large-Scale Gravity and Topography Anomalies. Ann. Revs. Earth and Planet. Sci. 9, in press, 1980.

Watts, A., and Daly, S.F., Lamont-Doherty Geological Observatory: Long Wavelength Gravity and Topography Anomalies. Ann. Rev. Earth Planet. Sci. 9, 415-448, 1981.

Wells, W.T., Korman, K., and Amann, D., Goddard Space Flight Center: Determination of Sea State From GEOS-3 Altimeter Waveform Statistics. EOS Trans. Amer. Geophys. Union, 1976.

Williams, J.G., Jet Propulsion Laboratory: Present Scientific Applications of Lunar Laser Ranging. In Scientific Applications of Lunar Laser Ranging, J.D. Mulholland, ed., D. Reidel, 37-50, 1977.

Williams, J.G., Sinclair, W.S., and Yoder, C.F., Jet Propulsion Laboratory: Tidal Acceleration of the Moon. Geophys. Res. Lett. 5, 943-946, 1978.

Wyatt, F., and Berger, Jr., University of California at San Diego: Investigations of Tilt Measurements Using Shallow Borehole Tiltmeters. J. Geophys. Res. 85, 4351-4362, 1980.

Wyatt, F., Beckstrom, K., and Berger, J., University of California at San Diego: The Optical Anchor - A Geophysical Strainmeter. Bull. Seism. Soc. Amer., submitted, 1981.

Wyatt, F., University of California at San Diego: Displacements of Surface Monuments - Horizontal Motion. J. Geophys. Res., to be submitted, 1981.

Yang, M., Massachusetts Institute of Technology: Time Dependent Tectonic Deformation and Stress of the Lithosphere after Earthquakes. EOS Trans. Amer. Geophys. Union 60, 316, 1980.

Yang, M., Massachusetts Institute of Technology: Time Dependent Tectonic Deformation and Stress of the Lithosphere. Ph.D. Thesis, Massachusetts Institute of Technology, 1980.

Yang, M., and Toksöz, M.N., Massachusetts Institute of Technology: Finite Element Models of Time Dependent Deformation and Stress Due to Strike-Slip Earthquakes. EOS Trans. Amer. Geophys. Union 60, 953, 1979.

Yang, M., and Toksöz, M.N., Massachusetts Institute of Technology: Time Dependent Deformation and Stress Relaxation After Strike-Slip Earthquakes. J. Geophys. Res., in press, 1981.

Yang, M., Toksöz, M.N., and Smith, A.T., Massachusetts Institute of Technology: Seismic Migration and Stress Diffusion in a Downgoing Slab. EOS Trans. Amer. Geophys. Union 58, 438, 1977.

Yang, M., Toksöz, M.N., and Smith, A.T., Massachusetts Institute of Technology: Thermoelastic Analysis of the Stresses in a Subduction Region. EOS Trans. Amer. Geophys. Union 58, 1233-1234, 1977.

Yionoulis, S.M., and Pisacane, V.L., Applied Physics Laboratory: Low-Low Gravsat Simulation Results. EOS Trans. Amer. Geophys. Union, 1979.

Yoder, C.F., Williams J.G., Sinclair, W.S., and Parke, M.E., Jet Propulsion Laboratory: Tidal Variations of the Earth Rotation. J. Geophys. Res. 86, 881-891, 1981.

Yoder, C.F., Williams, J.G., Parke, M.E., and Dickey, J.O., Jet Propulsion Laboratory: Short Period Tidal Variations of the Earth Rotation. Annales de Geophysique, in press, 1981.

Zwaan, H.G., and van Gelder, B.H.W., Delft University of Technology: The Influence of Precession on Relative Station Positioning From Satellite Laser Ranging by Long Arc Techniques. Dept. Geodesy, Delft Univ. Technology, in press, 1980.

REFERENCES

NAS, 1979: National Academy of Sciences, Committee on Geodesy: Applications of a Dedicated Gravitational Satellite Mission, Washington DC, 1979.

NASA, 1979a: National Aeronautics and Space Administration, Application of Space Technology to Crustal Dynamics and Earthquake Research: NASA Technical Paper TP-1464, August, 1979.

NASA, 1979b: National Aeronautics and Space Administration, Geodynamics Program Office: Very Long Baseline Radio Interferometry Programs, Status and Plans, December 1979.

NASA, 1980a: National Aeronautics and Space Administration, Geodynamics Program Office: Laser Ranging System Development for Crustal Dynamics Applications, December 1980.

NASA, 1980b: National Aeronautics and Space Administration, Geodynamics Program Office: The Requirements and Feasibility of the Gravsat Mission; A Report of the Gravsat Users Working Group, August 1980.

NASA, 1980c: National Aeronautics and Space Administration, Geodynamics Program Office, Annual Report for 1979: NASA TM-81978, May 1980.

NASA et al., 1979: National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, US Geological Survey, National Science Foundation, and Defense Mapping Agency: The Coordinated Federal Program for the Application of Space Technology to Crustal Dynamics and Earthquake Research, Washington DC, 1979.

NASA et al., 1980a: National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, US Geological Survey, National Science Foundation, and Defense Mapping Agency: Interagency Coordination Plan for Development of the Application of the NAVSTAR Global Positioning System (GPS) for Geodetic Surveying, Washington DC, July 1980.

NASA et al., 1980b: National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, US Geological Survey, National Science Foundation, and Defense Mapping Agency, Interagency Plan for Coordination and Use of Earth Gravity Field Survey Data From Space, Washington DC, July 1980.

Figure Captions

1. Mobile VLBI station MV-3.

2. TLRS-1 during checkout at the University of Texas at Austin.

3. TLRS-2 in the laboratory at the Goddard Space Flight Center.

4. VLBI/laser intercomparison sites. Figures on each baseline are deviations (laser minus VLBI) between baseline measurments, in centimeters.

5. Sites planned for occupation to measure regional deformation in North America, 1980-86.

6. Sites planned for occupation to measure crustal deformation in California.

7. Artist conception of Magsat spacecraft in orbit. Magnetometers were mounted on the extension boom.

8. Gravsat satellite concept. Satellite-to-satellite tracking antennas protrude above and below the spacecraft. The second spacecraft is in the background. TDRSS antennas are the strips across the nose and tail of the spacecraft.

9. Global atmospheric angular momentum compared to length-of-day observations, January 1976 through April 1980.

10. Polar motion: comparison between VLBI and Lageos laser ranging measurements during 1980 MERIT observing campaign. (a) x-component of pole position; (b) y-component of pole position.

11. Baseline length changes, Quincy to Otay Mountain (California), from San Andreas Fault Experiment, 1972-1979.

12. Baseline length residuals, Haystack Observatory (Massachusetts) to Owens Valley Radio Observatory (California), September 1976 through September 1980.

13. Polar motion and earth rotation based on Lageos observations, May 1976 through December 1979.

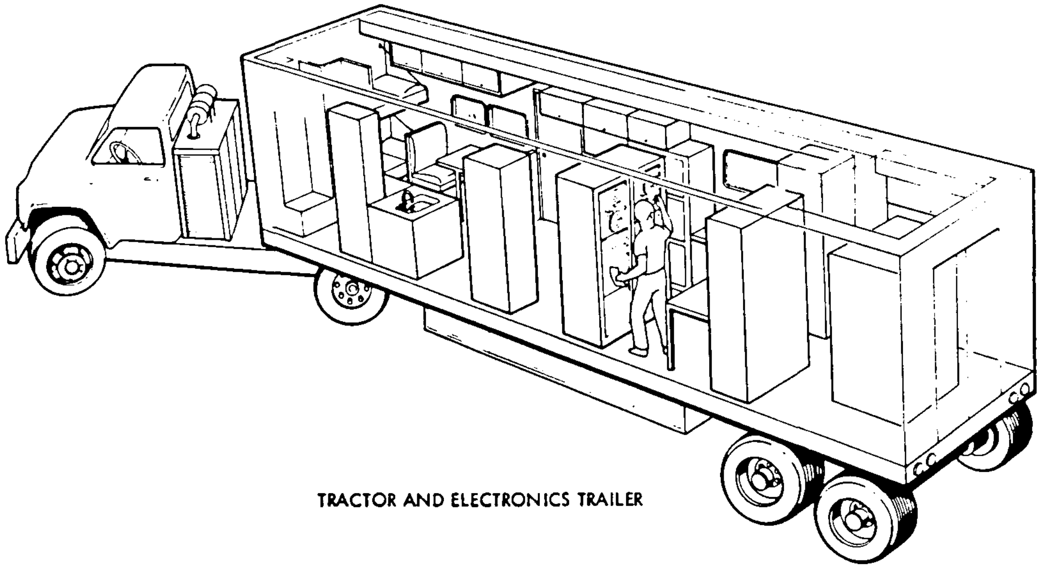
14. Mean sea surface topography based on Seasat altimeter data.

15. Magsat magnetic anomaly map.

16. Airborne Laser Ranging System block diagram.

17. Prototype SERIES unit at the Jet Propulsion Laboratory.

MOBILE VLBI STATION



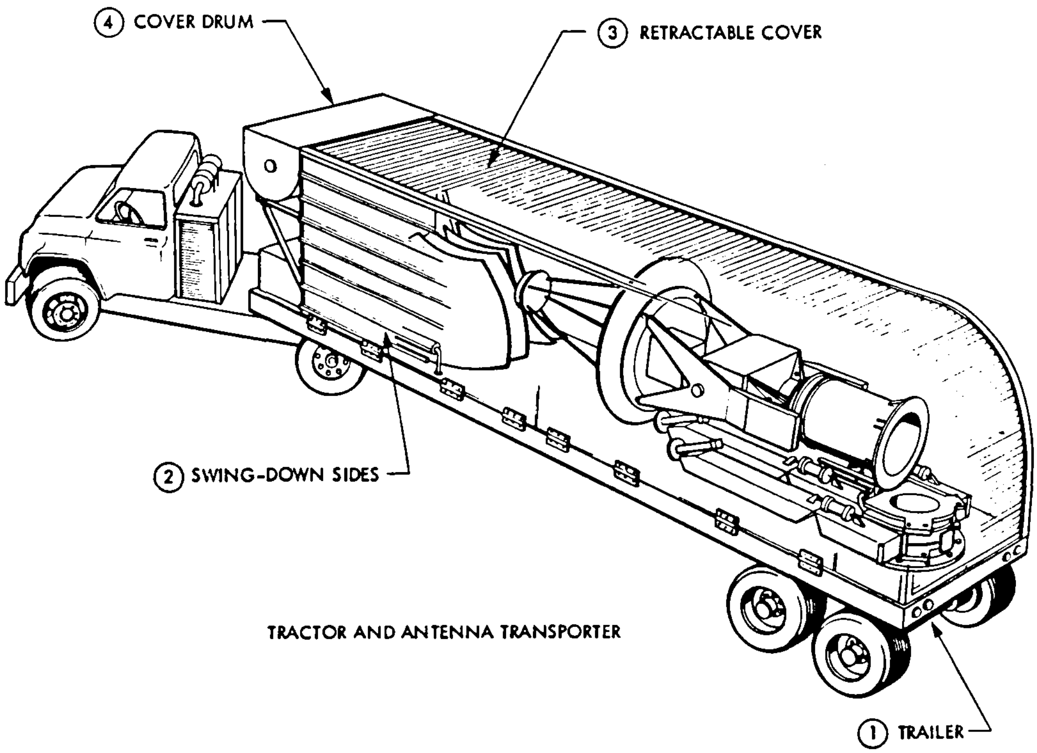


Figure 1.

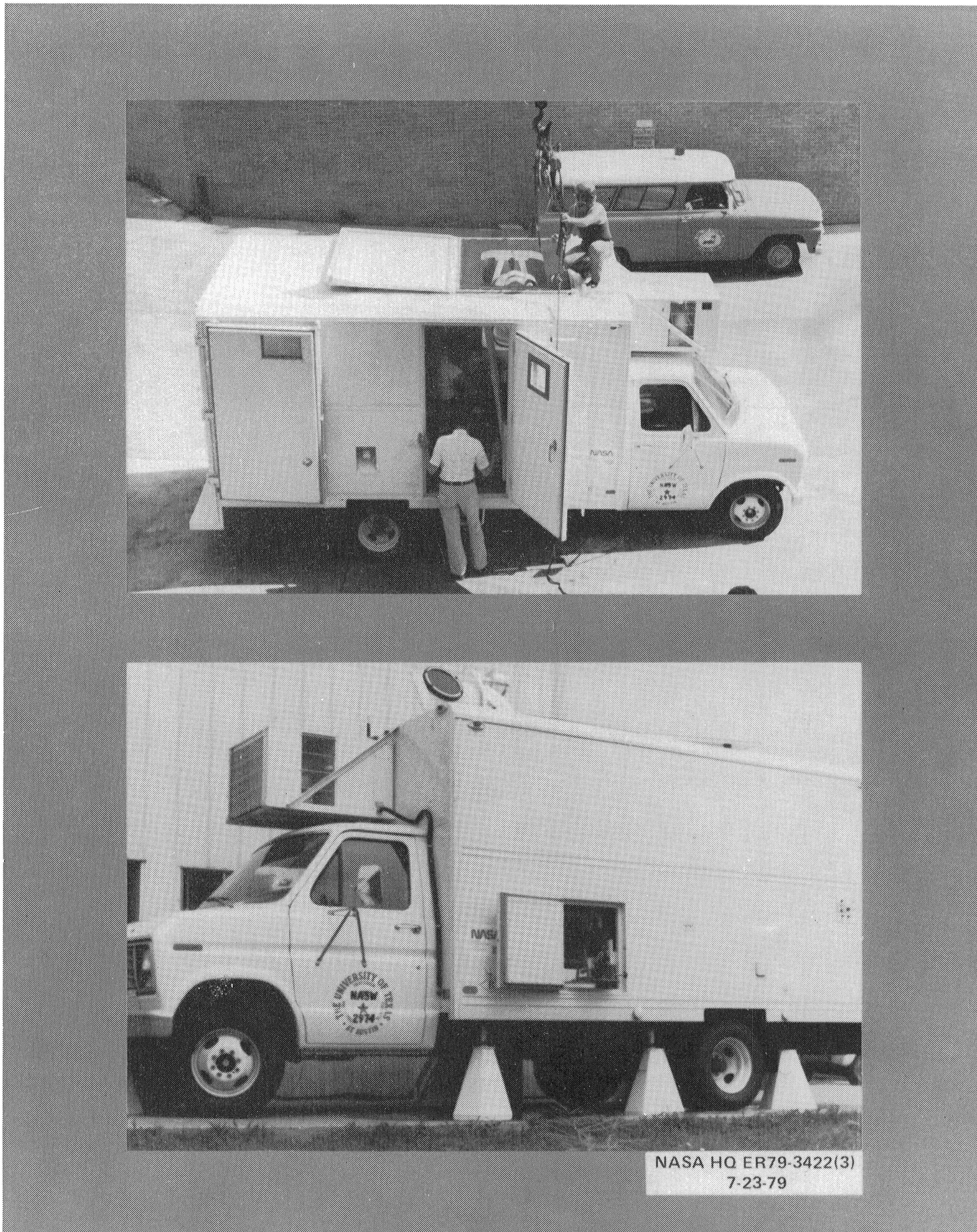


Figure 2.

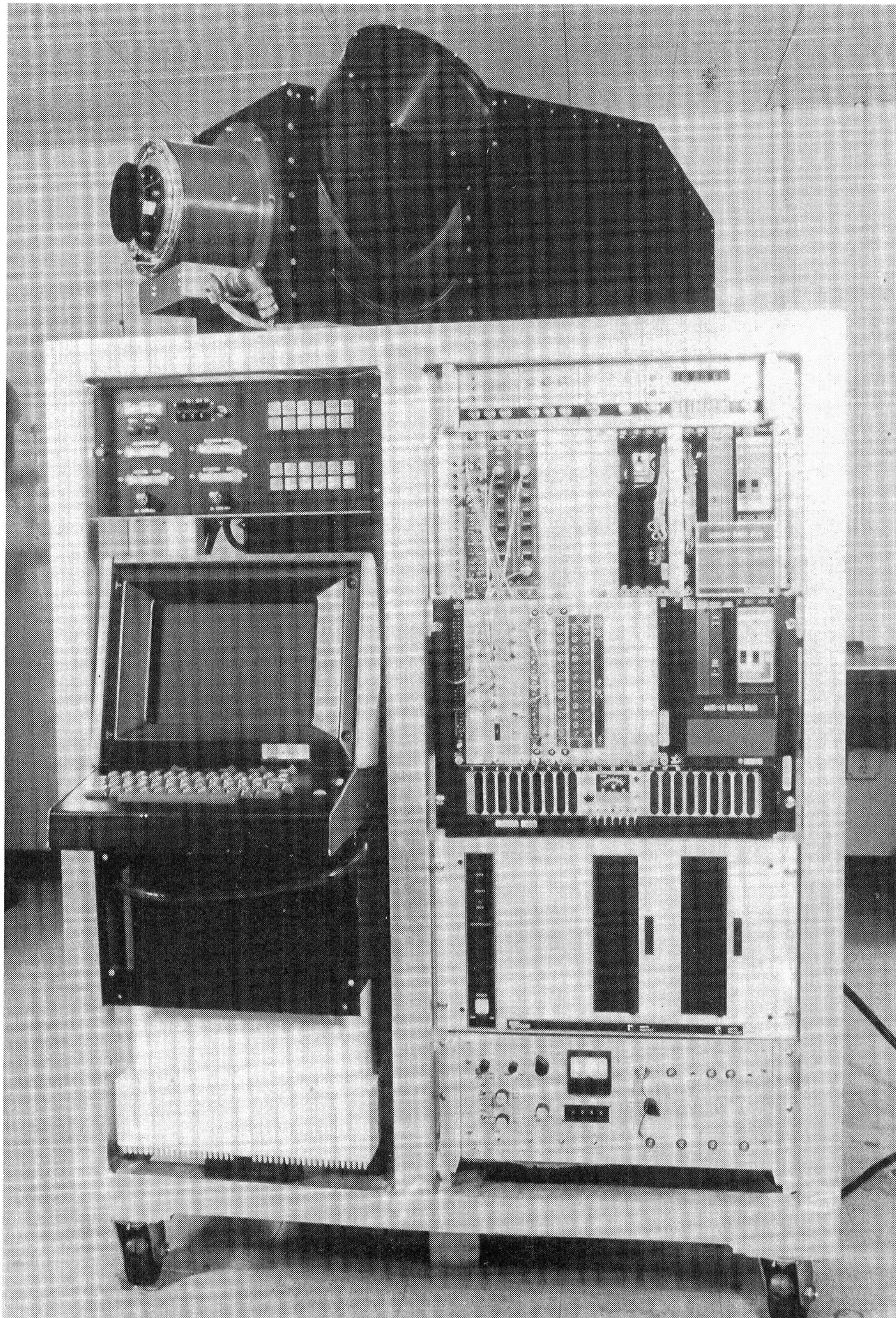
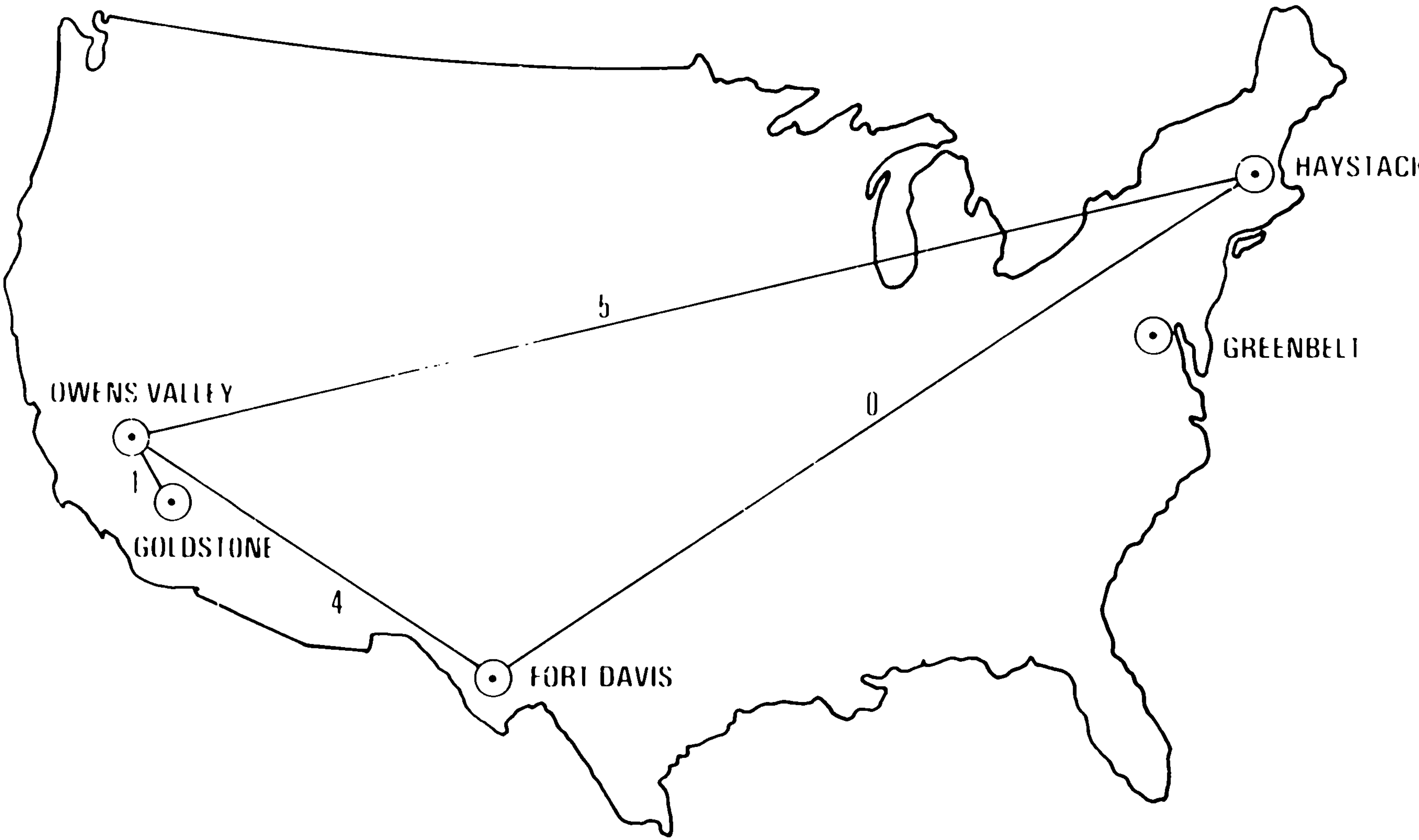


Figure 3.

TRANSCONTINENTAL BASELINE ACCURACY

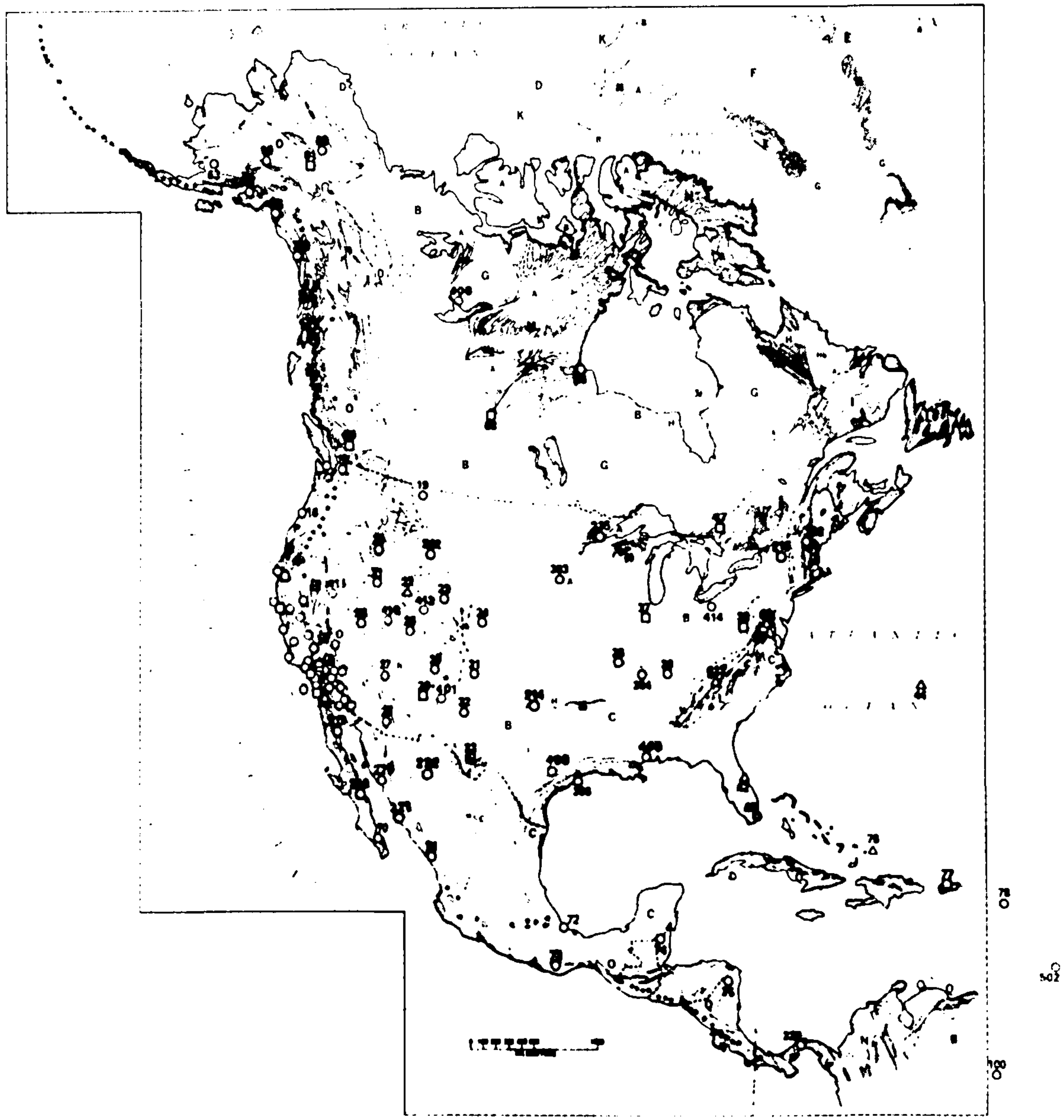
COMPARISON OF LASER AND VLBI BASELINES (CM)
(LASER MINUS VLBI)



NASA HQ E81-1248(1)
3-9-81

Figure 4.

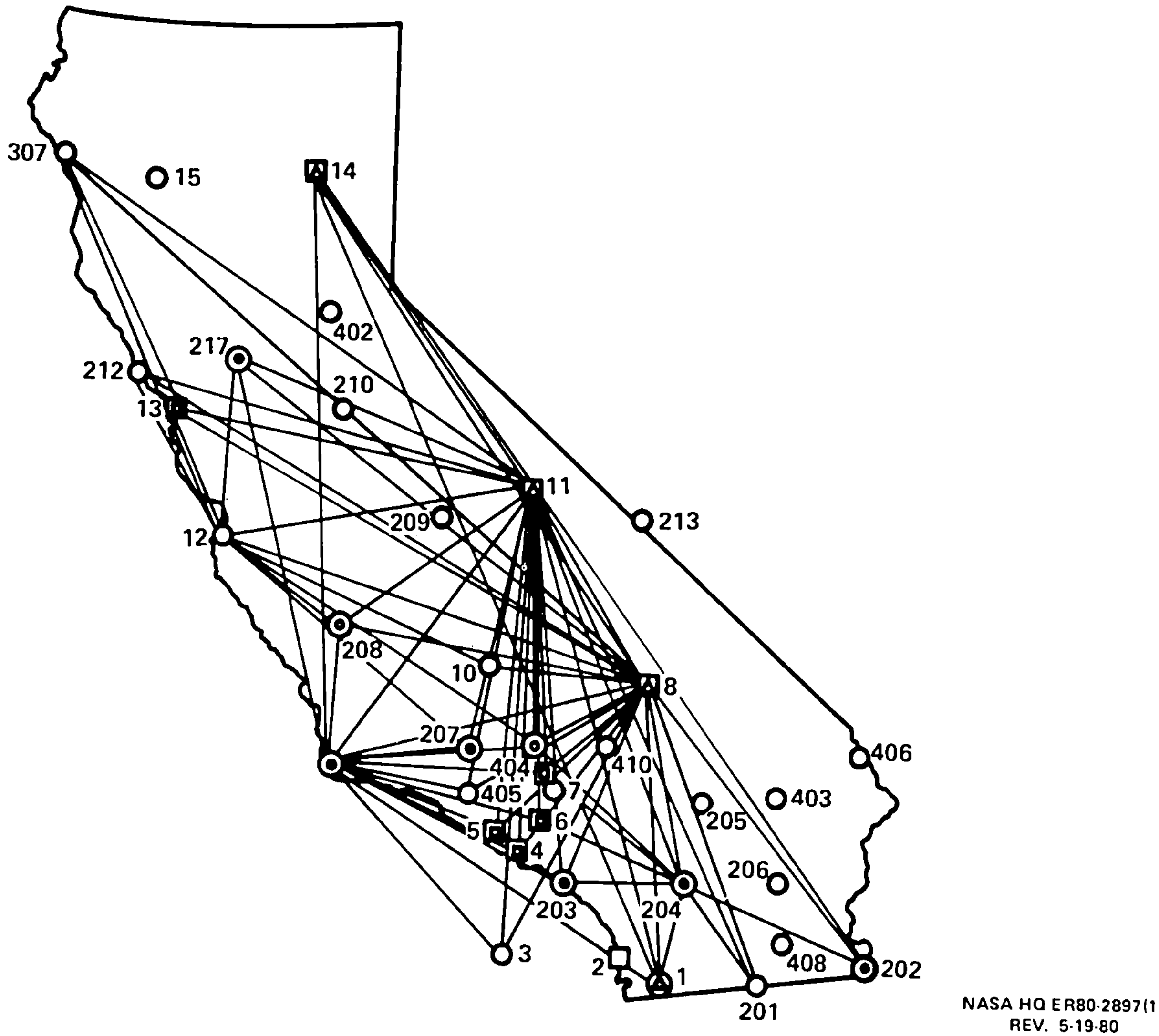
NORTH AMERICA REGIONAL DEFORMATION: 1980—1986



NASA HQ ER80 2405(2)
REV 5 19 80

Figure 5.

CALIFORNIA REGIONAL DEFORMATION



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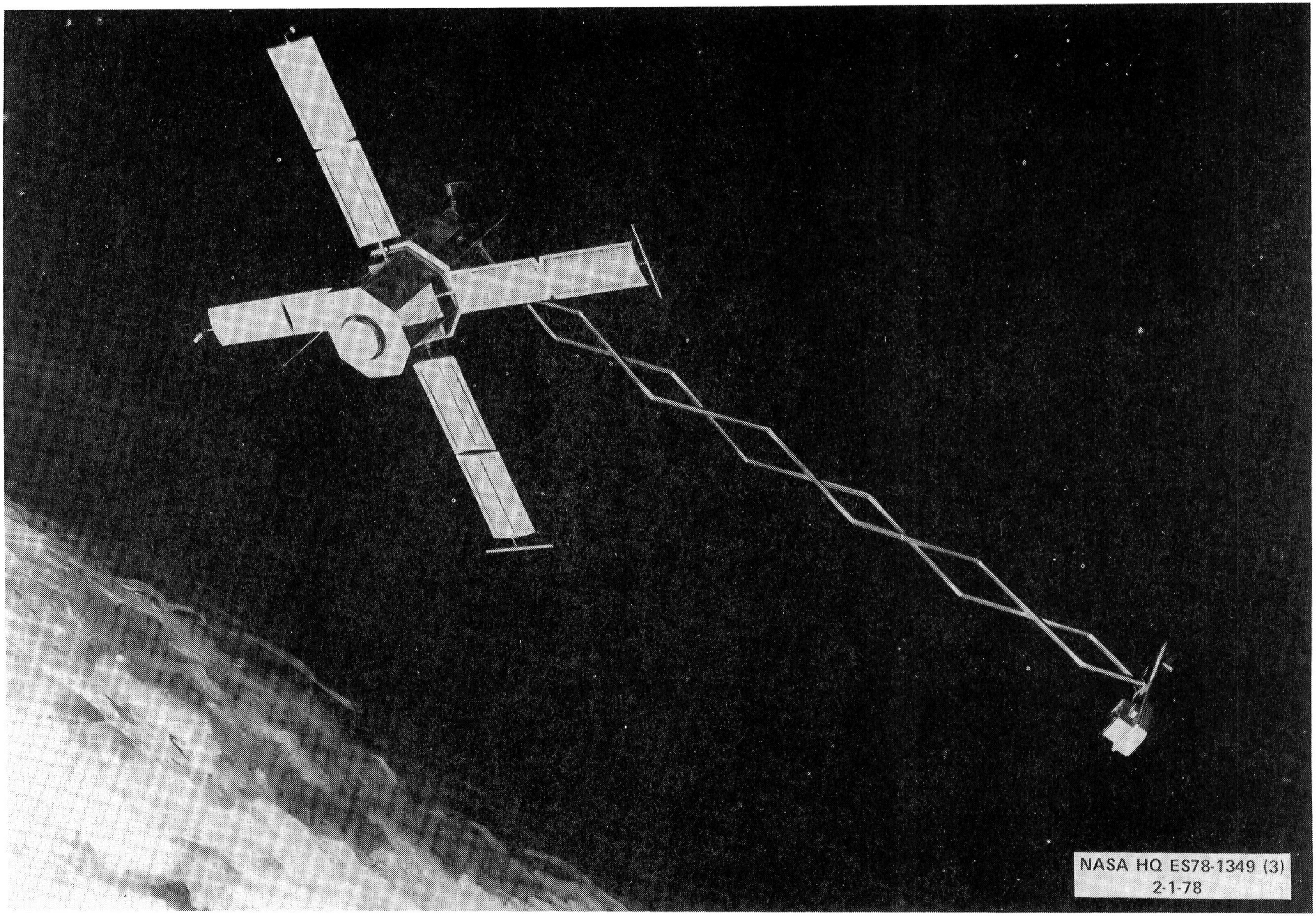


Figure 7.

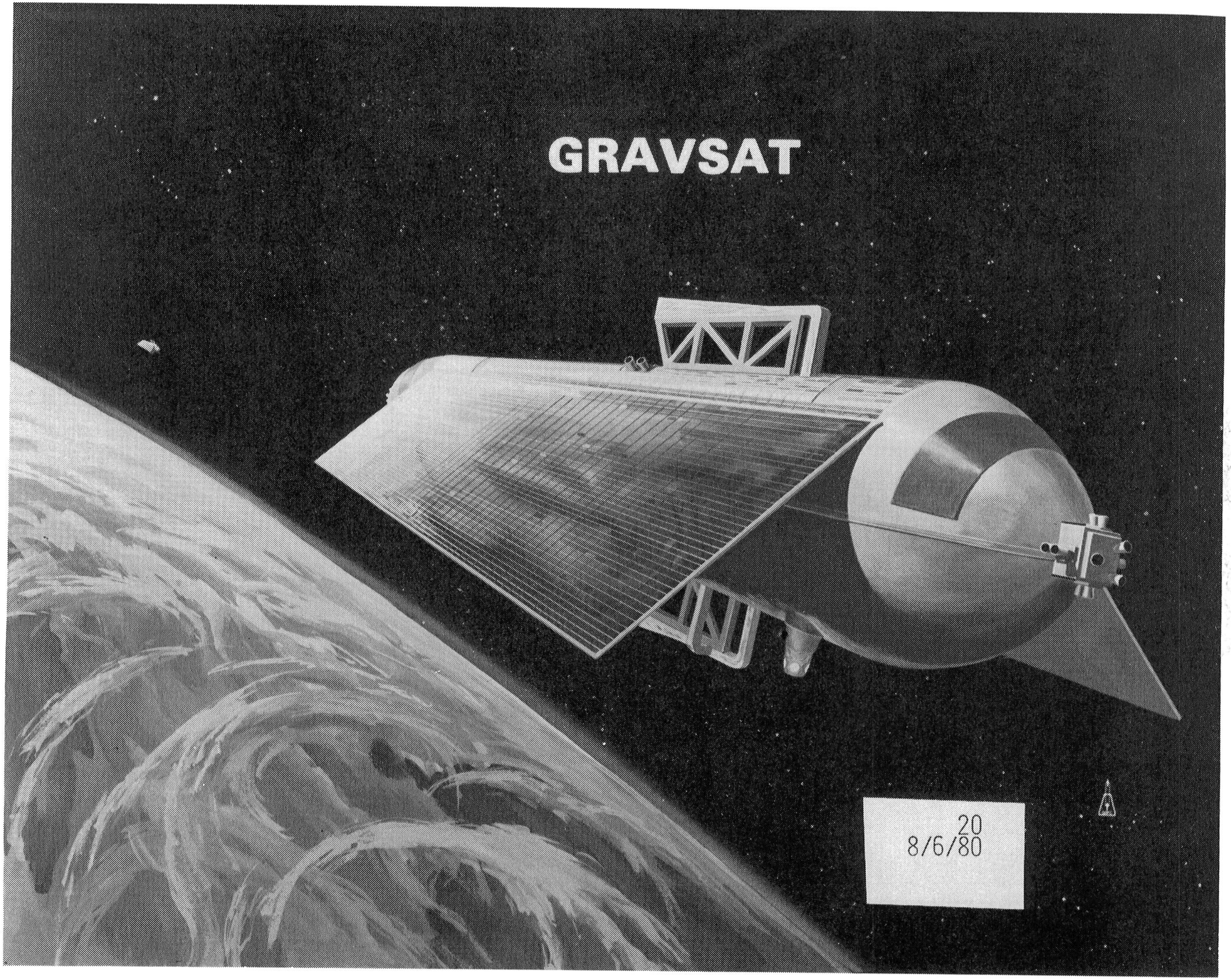


Figure 8.

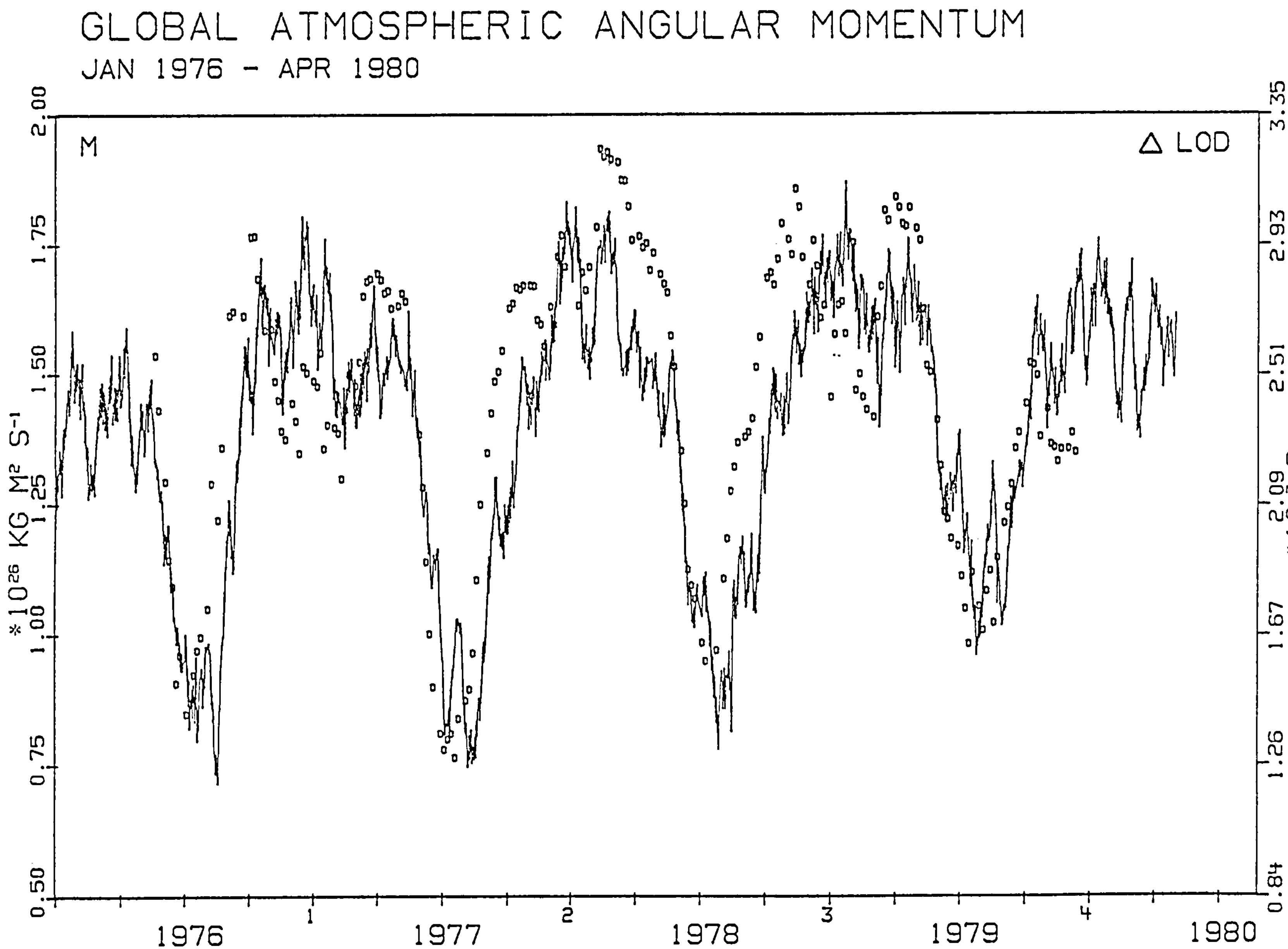

GLOBAL ATMOSPHERIC ANGULAR MOMENTUM
JAN 1976 - APR 1980
M
△ LOD
*10²⁶ KG M² S⁻¹
*10⁻³ S
2.00
1.75
1.50
1.25
1.00
0.75
0.50
3.35
2.93
2.51
2.09
1.67
1.26
0.84
1976
1977
1978
1979
1980
1
2
3
4

Figure 9.

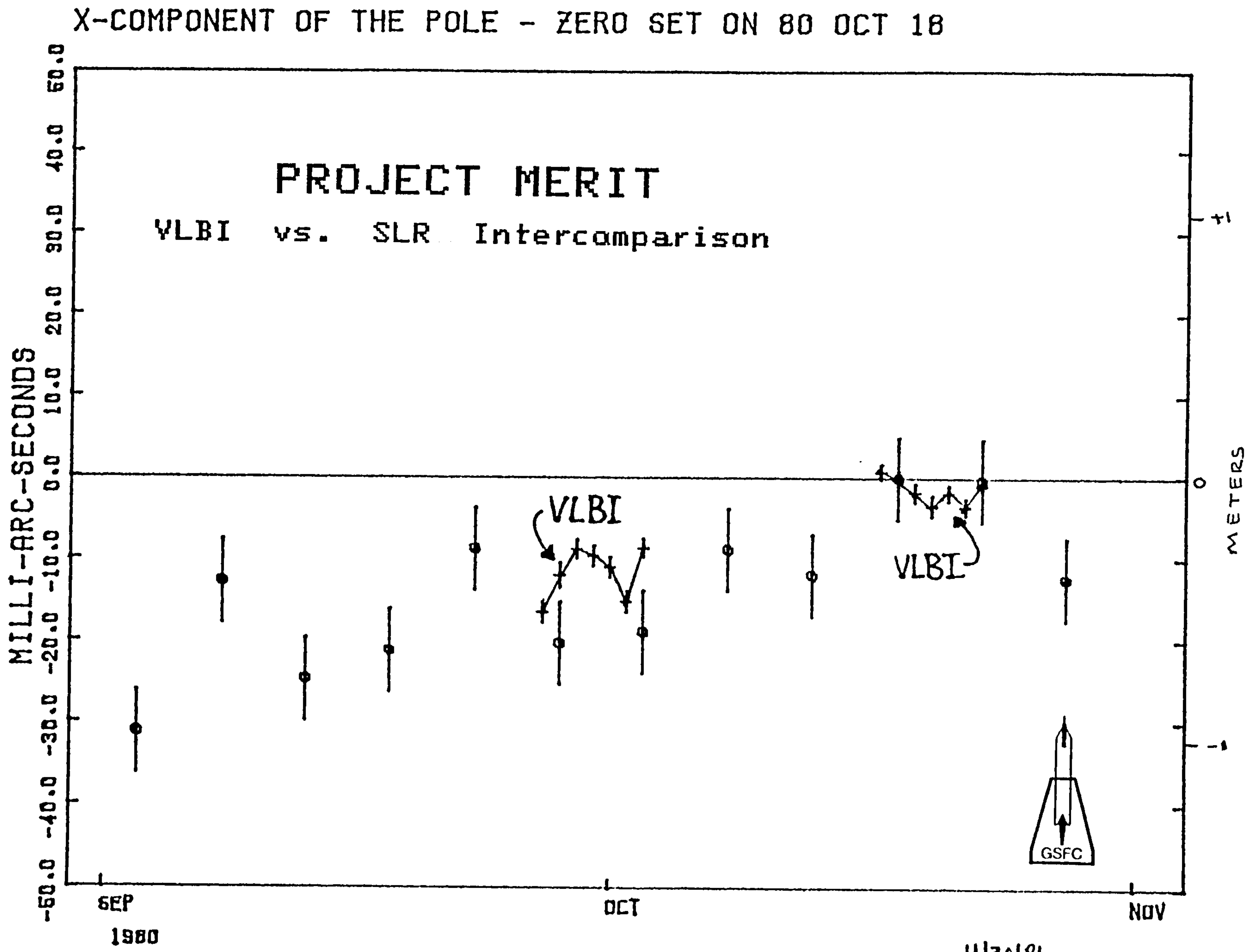

X-COMPONENT OF THE POLE - ZERO SET ON 80 OCT 18
PROJECT MERIT
VLBI vs. SLR Intercomparison
MILLI-ARC-SECONDS
60.0
40.0
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
METERS
+1
0
-1
VLBI
VLBI
SEP
1980
OCT
NOV
4/30/81
GSFC

Figure 10a.

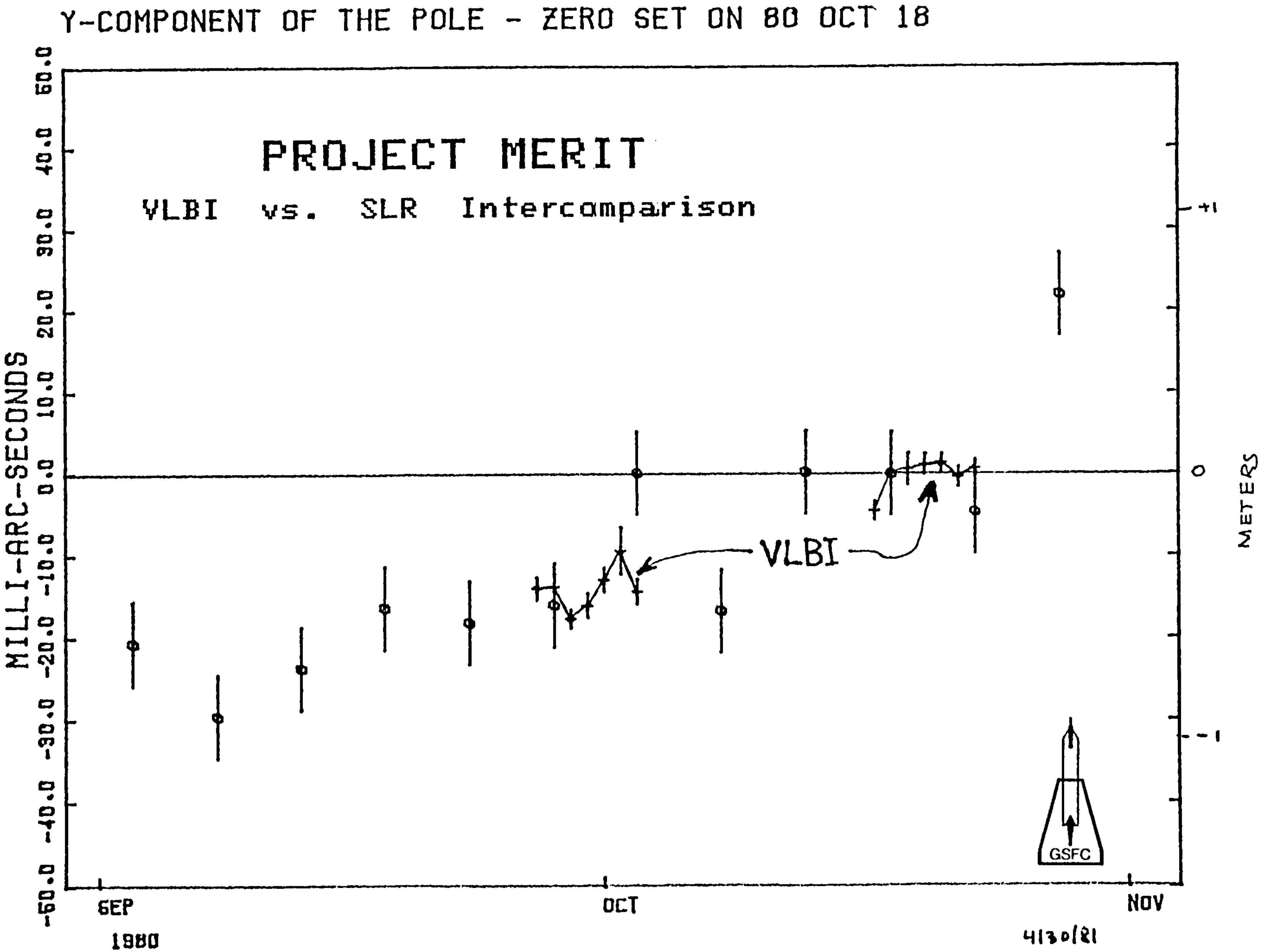

Y-COMPONENT OF THE POLE - ZERO SET ON 80 OCT 18
PROJECT MERIT
VLBI vs. SLR Intercomparison
MILLI-ARC-SECONDS
60.0
40.0
30.0
20.0
10.0
0.0
-10.0
-20.0
-30.0
-40.0
-50.0
METERS
+1
0
-1
VLBI
SEP
1980
OCT
NOV
4/30/81
GSFC

Figure 10b.

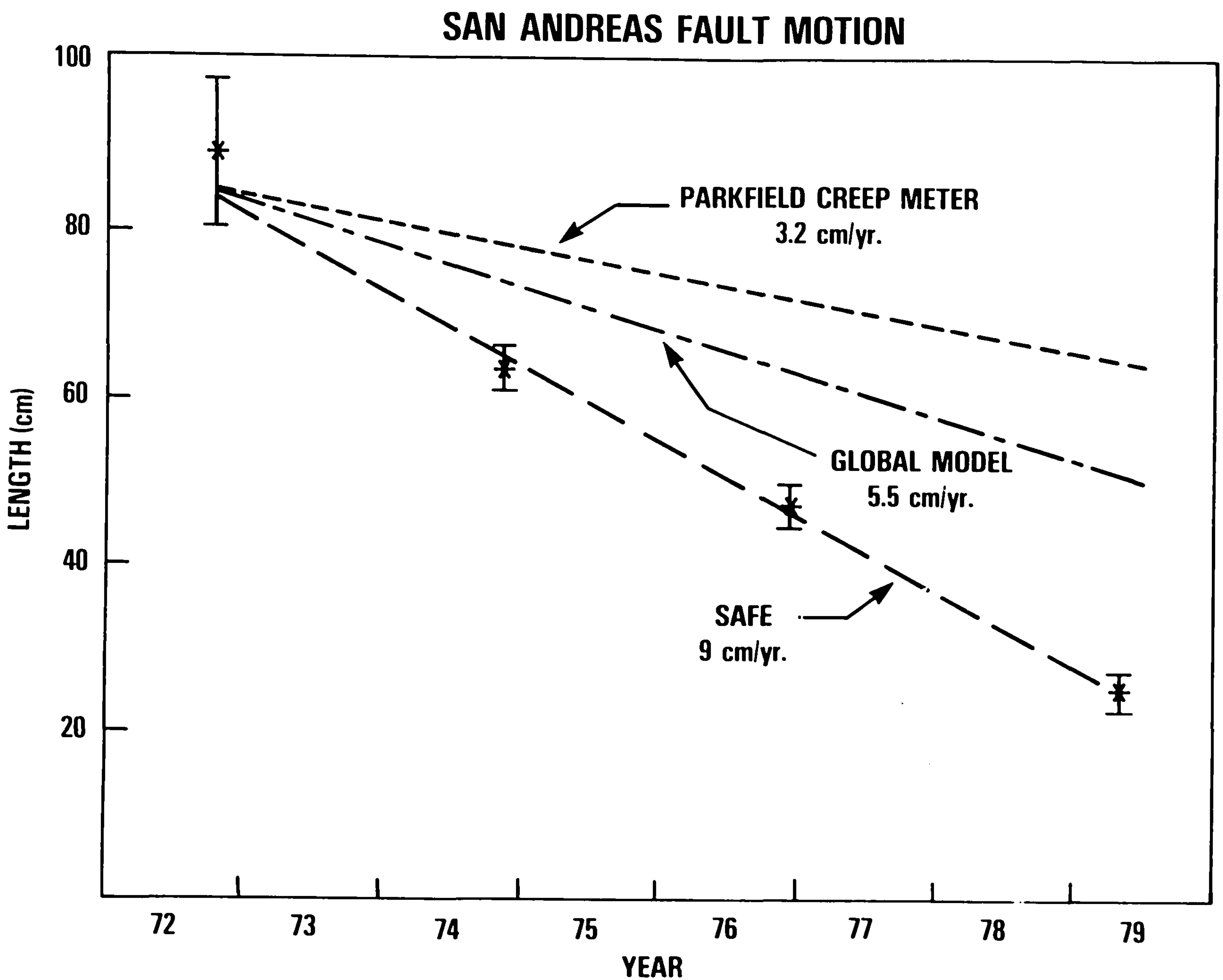
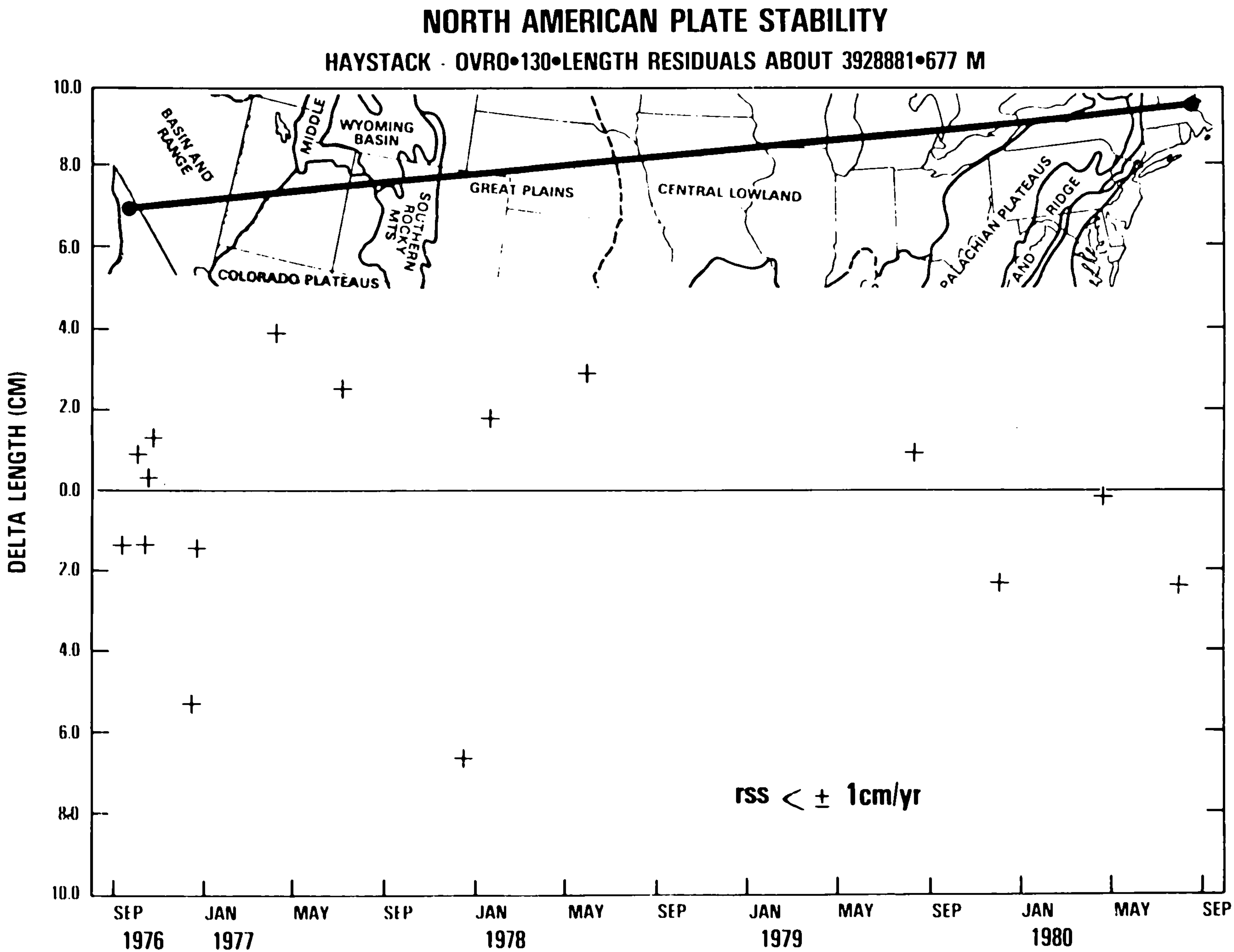
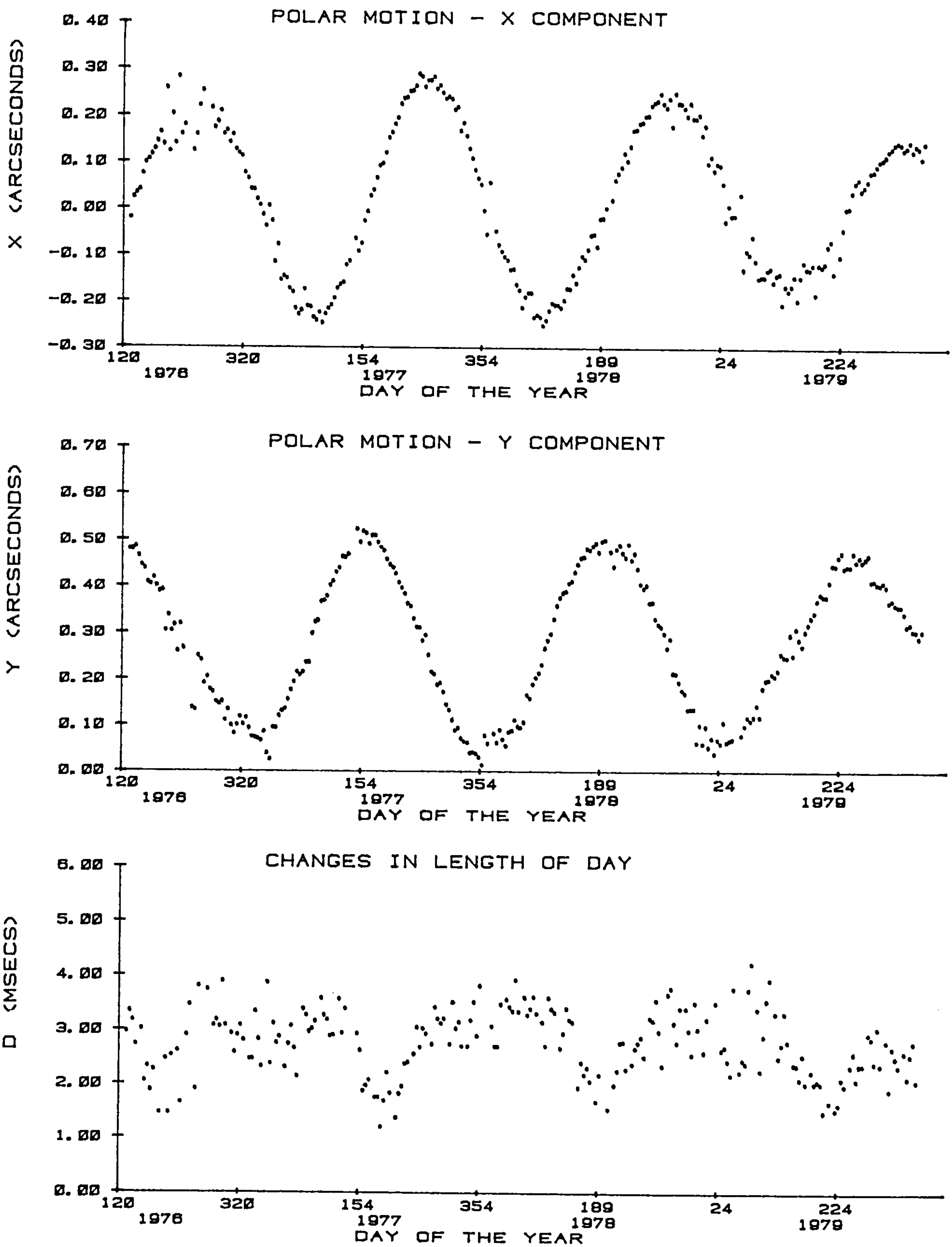

SAN ANDREAS FAULT MOTION
100
80
60
40
20
LENGTH (cm)
PARKFIELD CREEP METER
3.2 cm/yr.
GLOBAL MODEL
5.5 cm/yr.
SAFE
9 cm/yr.
72
73
74
75
76
77
78
79
YEAR

Figure 11.



NORTH AMERICAN PLATE STABILITY
HAYSTACK · OVRO•130•LENGTH RESIDUALS ABOUT 3928881•677 M
DELTA LENGTH (CM)
10.0
8.0
6.0
4.0
2.0
0.0
2.0
4.0
6.0
8.0
10.0
BASIN AND RANGE
MIDDLE
WYOMING BASIN
SOUTHERN ROCKY MTS
COLORADO PLATEAUS
GREAT PLAINS
CENTRAL LOWLAND
APPALACHIAN PLATEAUS
AND RIDGE
rss < ± 1cm/yr
SEP
JAN
MAY
SEP
JAN
MAY
SEP
JAN
MAY
SEP
JAN
MAY
SEP
1976
1977
1978
1979
1980

Figure 12.



LAGEOS POLAR MOTION AND EARTH ROTATION, MAY '76 - DEC '79

Figure 13.

MEAN SEA SURFACE TOPOGRAPHY BASED UPON SEASAT ALTIMETER DATA

18 DAYS — JULY 28 TO AUGUST 15, 1978
1° GRID, 2M CONTOUR
$a_e = 6378140$ M, $\frac{1}{F} = 298.255$
(GSFC PGS S4 ORBITS)

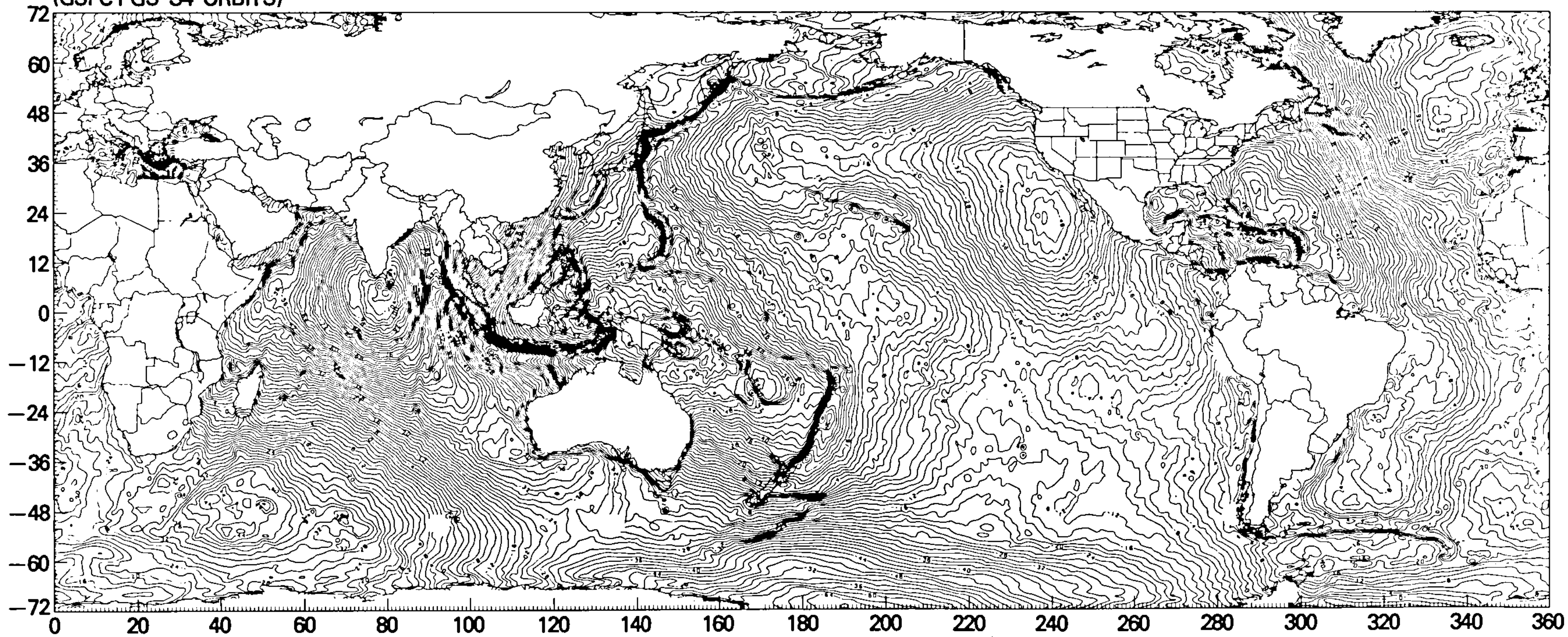


Figure 14.

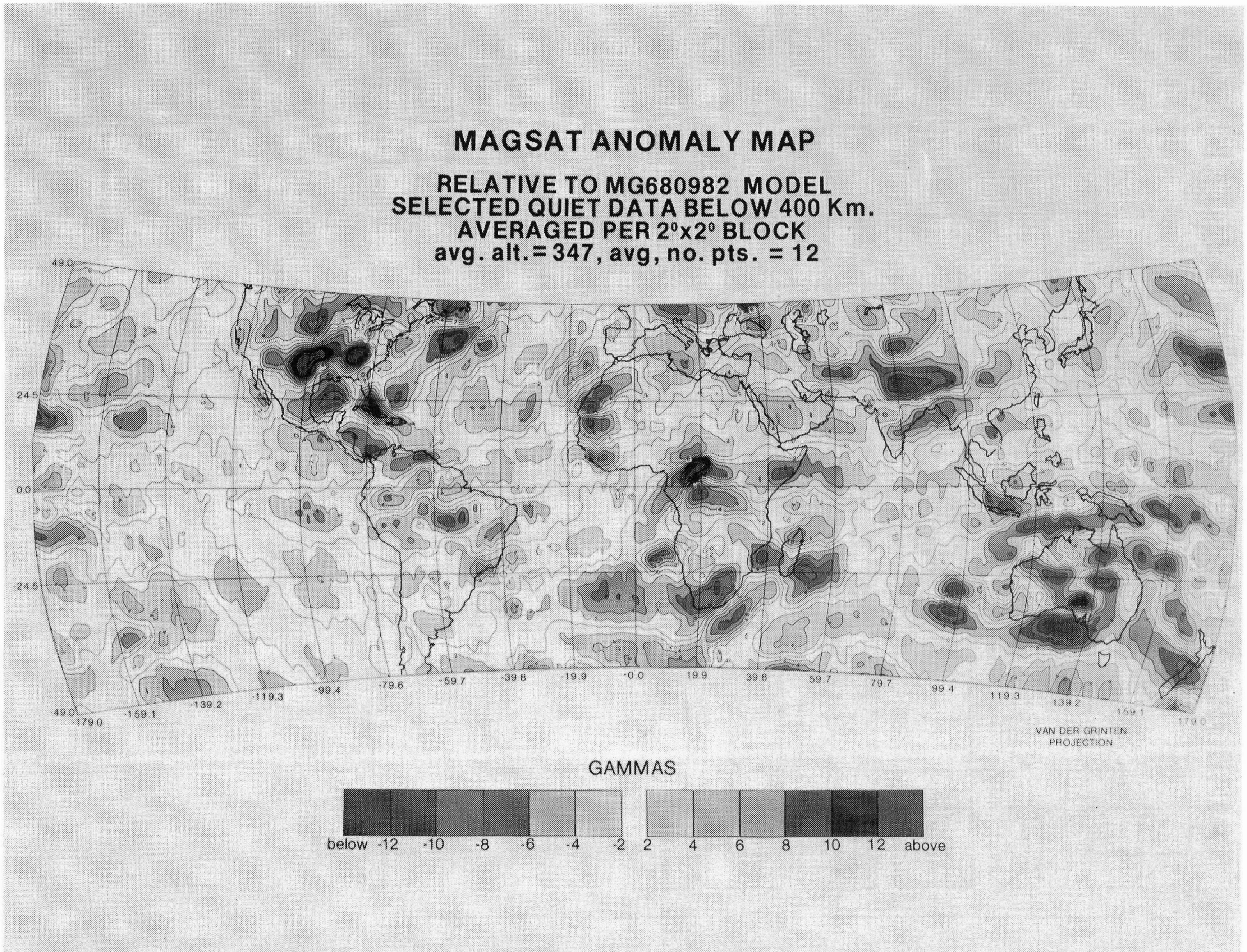

MAGSAT ANOMALY MAP
RELATIVE TO MG680982 MODEL
SELECTED QUIET DATA BELOW 400 Km.
AVERAGED PER 2°x2° BLOCK
avg. alt.= 347, avg, no. pts. = 12
49.0
24.5
0.0
-24.5
-49.0
-179.0
-159.1
-139.2
-119.3
-99.4
-79.6
-59.7
-39.8
-19.9
-0.0
19.9
39.8
59.7
79.7
99.4
119.3
139.2
159.1
179.0
VAN DER GRINTEN
PROJECTION
GAMMAS
below -12 -10 -8 -6 -4 -2 2 4 6 8 10 12 above

Figure 15.

AIRBORNE LASER RANGING SYSTEM

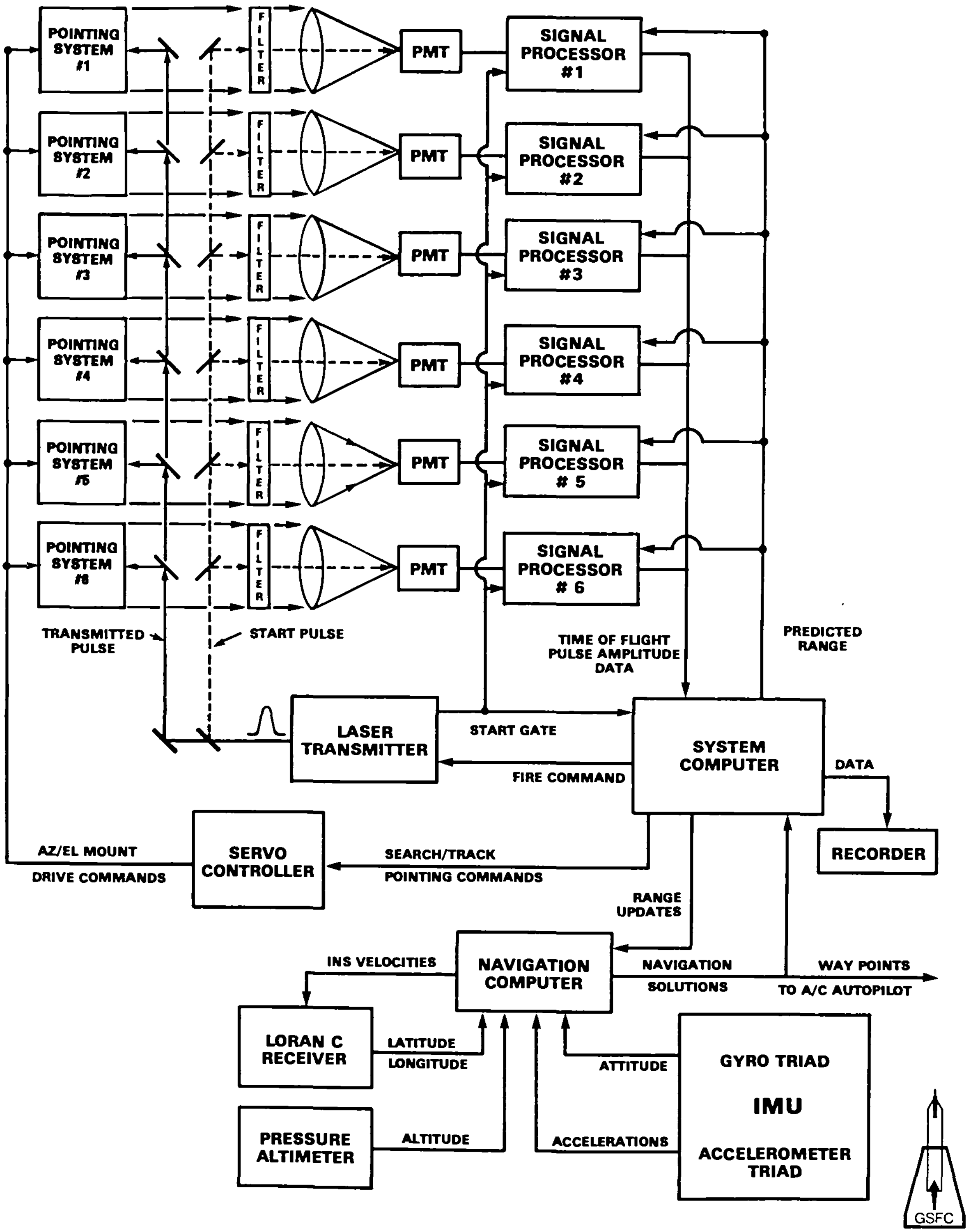


Figure 16.

Figure 17.

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4. Title and Subtitle NASA Geodynamics Program: Annual Report for 1980		5. Report Date October 1981
		6. Performing Organization Code ERG-2
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9. Performing Organization Name and Address Geodynamics Branch Resource Observation Division Office of Space and Terrestrial Applications		11. Contract or Grant No.
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15. Supplementary Notes		

16. Abstract

This is the second annual report of activities of the NASA Geodynamics Program. The history and development of the program are described in the first annual report published in May 1980. This document gives the status, progress, and future plans of the program and for the first time includes a list of publications of research results supported by the program.

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